Laboratory. Pemberandah.

A TEXT-BOOK

ON

INDIAN AGRICULTURE

BY

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VOL. I.

SOILS, MANURES, IMPLEMENTS.

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PREFACE.

This volume is the first of three which together comprise a text-book on Indian agriculture. The collection and compilation of the subject matter has been going on for some years, and has given the writer agreeable occupation in his spare time. The work is arranged to meet the requirements of the Syllabus of the Bombay University for the Degree in Agriculture, and it is hoped that it will prove useful to Agricultural Students and Teachers, educated Agriculturists, and Government officials in the Revenue service.

I am largely indebted to Dr. Leather, Agricultural Chemist to the Government of India, for numerous analyses of Indian soils, manures and feeding stuffs, and also for photographs for illustrations. I have freely taken advantage of information on record in the Bombay Agricultural Department, and have exploited published works for authentic information on Indian agricultural matters. I only take credit for publishing a work which meets a want. The illustrations are prepared by F. B. Stewart, Photographic Artist, Poona. I am indebted to the office establishment of the Survey Commissioner and Director, Land Records and Agriculture, for examination and correction of proofs, and in particular to Mr. Yeshwant Nilkanth, the Superintendent of that office.

J. M.

Poona, January, 1901.

VOLUME I.

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SOIL FORMATION.

The conversi[on of] rocky material [into] soil material.

Soils are those friable portions of the Earth's surface which can be tilled and are capable of supporting vegetation. Soil forms a superficial layer of variable thickness. By digging down a certain depth unchanged rock material is invariably found. By disintegration and decomposition this rocky material can be converted into soil material. We may take it as certain that at one time in the world's history soils did not exist as we see them now. Their formation has been gradual. Water has been a powerful agent in all ages not only in directly forming soils, but also in the formation of those stratified rocks which when exposed to weathering influences yield by disintegration soil material. Rain-water when it falls upon the earth either soaks into it or flows over its surface. It drains off the surface of land first in little streams. These join and form larger streams, which as they course onwards increase in volume by the inflow of their tributaries. Finally, they empty themselves into lakes or into the ocean. Running water has a very powerful effect in changing the earth's surface. Wherever it flows it furrows out for itself channels more or less large. In whatever direction it moves, it carries with it the material which it wears away from rocks or removes from existing soils. It is therefore called a *denuding agent.* Its power in this respect can be noticed by observing what goes on around us.

The denuding [action] of flowing water

In India we have a rainy season—a season, when a considerable rainfall is experienced in a short period. On the Western Ghats of the Bombay Presidency, often one hundred inches of rain fall in a few months. This represents approximately 10,000 tons of water on each acre of surface. This water as it drains rapidly down the slopes and steep precipices of these hills carries with it much denuded material. We may notice at the time that the water is obviously discoloured and if we take the trouble to examine some of these hill-sides later on, say in the hot weather when there is no rain and very little drainage, we shall find the exposed face of the hard rocks a network of grooves and furrows which have been cut out by the wearing action of running water. In the rains most of our rivers are in flood and their waters are muddy. In the hot season, however, they are nearly dry. An exception to this rule is the Indus which begins to rise in the hot season, because it is fed by the snow of the Himalayas which begins to melt when the hot weather sets in. Where a river overflows its banks an appreciable deposit of fine mud will be found on the flooded land when the water recedes. Similar deposits may have been formed annually and we can well understand how a soil layer of considerable thickness would accumulate in the course of years. Where the water runs slow, the mud is deposited in the greatest degree. Sluggish rivers

flowing into an ocean form deltas—the Ganges and Brahmaputra are examples. If the river flows quick the material is carried out to sea and deposited on the ocean floor—the Amazon is an example. If the material is deposited as a superlayer above existing soil, an alluvial soil is being added to; if in the bed of a lake or in the ocean, stratified rocks are being formed.

Soils produced from three distinct classes of rocks through weathering influences.

The actual formation of stratified rocks pertains more to Geology than to Agriculture. It is sufficient to know that they have been formed by the action of water, &c., and that by the latent heat of the earth they have been upheaved and now form part of the dry land. If, instead of being upheaved, they were depressed and subjected to the influences of the heat which we know exists at the centre of the earth, they become somewhat modified, lose their stratified appearance, and become more or less crystalline in structure and are called metamorphic. These upheaved to the surface by volcanic action now form part of the earth's crust. We have therefore in the present age three distinct types of rocks forming the earth's surface which when subjected to certain weathering influences, that will be referred to presently, yield by disintegration soil material.

The three classes of rocks are :—

1. Primitive or igneous ; *e.g.* Granite.
2. Metamorphic ; *e.g.* Marble.
3. Stratified ; *e.g.* Limestone.

Sedentary and transported soils.

Soils may be of two kinds, sedentary and transported. A sedentary soil is formed from the underlying rock and resembles it in character and composition. Transported soil has been carried by the transporting power of water or wind and deposited on a rock which it need not necessarily resemble.

Minerals of agricultural importance.

In whatever manner the soil has been formed its fertility depends greatly upon the mineral fragments which it contains; therefore the composition (chemically) of the rock or rocks from which it has been formed is of prime importance. The minerals of agricultural importance found in rocks are: Felspar, hornblende, quartz, mica, talc, carbonates of lime and magnesia, and others of minor importance.

Natural forces which cause disintegration.

Rock disintegration and soil formation are attributable to certain forces of nature, which have been in operation during all ages and are actively at work now. These are :—

1. Water in its various forms.
2. The atmosphere.
3. Variations in temperature.
4. Vegetable and animal action.
5. Volcanic action.

Taking these in the order named, we have to notice the action of water in other respects than those already referred to. We have already seen how sluggish streams form deltas, and deposit alluvial beds along their flooded banks. All running water contains sediment in suspension not always observable by the naked eye. But nevertheless river water that appears clear is actually not so. The material held in suspension represents the effect of the denuding power of water. Water exercises also a solvent effect on rock and soil material. If common salt is mixed with water the salt disappears and becomes dissolved in the water. Water exercises a similar effect on certain ingredients found in rocks and particularly so, if it contains oxygen or carbonic acid gas.

Denuding and solvent effect of water.

The waves of the ocean beating on a shore are powerful denuding agents. Angular pieces of rock may be broken off, and these when rolled about by an angry sea are smashed up into small fragments and rounded into water-worn pebbles, gravel and sand. The ebb and flow of the tides carry away and deposit this denuded material elsewhere, often in the bed of the ocean, but sometimes the dry land or shore is being added to.

Effect of waves and tides.

Water is an exception to an almost universal law in nature, *viz*, when bodies are heated they expand, when cooled they contract. Water, however, contracts as it is cooled until it reaches the freezing point. In the act of freezing it suddenly expands about $\frac{1}{10}$th of its bulk. Rain or water will soak into the substance of a rock, and fill up all cracks and fissures which there exist. In winter time in most countries the temperature is often below the freezing point, and the water which has found its way into the substance of a rock is turned into ice and suddenly expands with irresistible force. The particles of the rock are disrupted and the natural fissures forced further asunder. The full effect does not appear until the weather gets warmer and the ice melts. Then fragments, more or less bulky, fall away, and loosened particles of smaller size are, at the same time, conveyed away by the water which trickles from the rock.

The effect of freezing of water.

Icebergs are usually seen as vast blocks of ice floating in mid-ocean. They are nowadays, as they have been throughout long ages, carriers of soil material. As we see them in the ocean only about $\frac{1}{3}$ of their substance appears above water. They are each of them weighed down by a huge load of boulders, gravel, sand and earth. Each iceberg once formed a mass of ice attached to a shore in the Arctic or Antarctic regions, and was driven on to the beach by the action of the sea. In this way the boulders and earth-material became incorporated with the ice. This would occur during winter. But a short summer would come once a year when the ice becoming partially melted would; by the ebb of the tide, be carried out to sea to be conveyed towards the Equator by ocean-currents, and in a warmer temperature the iceberg would gradually melt and discharge its load.

The effect of Icebergs.

The effect of glaciers.

Glaciers are ice rivers formed in mountainous regions of perpetual snow. These ice rivers travel slowly carrying with them much denuded material, scratching and polishing the rock surface over which they move. At some point in the valley below, the temperature is above the freezing point and there the ice is melted and the disintegrated rock-fragments are further transported by the stream which here has its origin. The Indus is fed by the melted snow and ice of the Himalayas. This river is in flood in the hot weather because the mean temperature is higher in the Himalayas at this season than at any other, and consequently the snow except in the higher peaks disappears. The hill streams carry down enormous quantities of denuded material of which more or less is conveyed finally by the Indus to be deposited upon the vast stretches of cultivated land which that river annually inundates, and also upon the lands which the Indus canals irrigate. The alluvium thus added to a pre-existing soil helps to enrich it.

The effect of the atmosphere on soil formation is chemical as well as mechanical. We can hardly appreciate its chemical action until we know approximately its composition. It consists roughly of

4/5	Nitrogen	recognised by the chemical	symbol	*N*
1/5	Oxygen	do.	do.	*O*

Atmospheric effect on soil formation, particularly the effect of oxygen and carbonic acid gas.

In 10,000 parts of air there are 4 parts carbonic acid gas recognized by the chemical formula CO_2. We may dispense with nitrogen as an inactive agent in the formation, but by no means in the fertilization of soils, not so with oxygen. It has an extraordinary avidity to combine with substances found in nature, and this is increased by the presence of moisture. We will instance the case of iron. If we expose it to the atmosphere it rusts. Rust appears as a bulky red brown powder friable and easily removed. The iron has combined chemically with the oxygen of the air. This is oxidation. If the rust is rubbed away, the iron, if again exposed, is similarly acted upon. If the iron is wet the rust forms much more quickly than if dry. In all rocks there are various minerals which contain constituents that are readily oxidized, and as the resulting oxide is bulkier than its mineral base, disruptions of rock particles must follow. In soils of even a primitive kind organic matter got from the decaying roots and other tissues of plants, etc., exists. Under exposure to the influence of the atmosphere this organic matter decays. This is due to oxidation. The results are that CO_2 is produced, also organic acids and other products. The organic acids especially have a solvent action on such mineral matter of a soil as is not soluble in pure water. The action of carbonic acid gas, if not quite as energetic as oxygen, is probably as powerful. It is soluble in rain-water and is then a mild acid. Although its action is slow it is irresistible. It shows its dissolving effect not only on hard rock material but also on the mineral matters of soils already formed or being formed. The CO_2 necessary for this action is derived not alone

from the atmosphere. The decomposition of the organic matter of the soil, *i.e.*, the decays of the roots and other remains of plant life or of manure, produces a considerable supply of CO_2, which having become dissolved in the water of the soil is brought into direct contact with the mineral matter of the soil and has a powerful dissolving influence. Mineral carbonates, such as carbonate of lime or carbonate of magnesia, &c., all more or less soluble, are the result of the above action.

Wind.

Soils transported through the agency of wind are common on exposed sea-coast districts. The loose sand of the shore is blown inland to form a low ridge as seen on the flat coasts of Surat and Broach.

Effect of variations of temperature.

Most bodies expand when heated and contract when cooled. But different substances contract and expand in different ratios when exposed to the same temperature. Thus the various minerals which compose the mass of a crystalline rock expand and contract in different proportions. The component particles are disturbed and disintegration follows.

Cracks in existing soils.

The effect of extreme high temperature is exemplified by noting the cracks that form in existing soils in India as well as other countries. Some of our black and heavy clay soils are said to "plough themselves" through this agency. And we know that the subsoil is thereby exposed to the action of the atmosphere and other weathering influences so that further disintegration follows.

Effect of difference between day and night temperatures.

The mean difference between day and night temperature in India is considerable. Rocks of a homogeneous character like sandstone, limestone or trap, subjected to extreme variations of temperature, split and have their structure shaken. A man who has to quarry stones knows this fact and takes practical advantage of it. When blasting powder is not available he heats the rock by burning cheap fuel thereon. When sufficiently hot, water is poured on the heated surface. This occasions sudden contraction which causes the rock to split and a crow-bar let into the cracks will remove the loosened fragments.

Vegetable action.

A primitive soil is only at first capable of supporting plant life of a very inferior description, such as mosses, lichens and the like. On the face of cliffs you will find these growing. But soils that have sufficient depth to hold moisture are capable of maintaining vegetation of a higher kind. The growth of vegetation particularly of large trees, exercises a disintegrating influence on soil or rock material, because the roots force themselves through the soil and subsoil, and even through fissures of underlying rock. As the roots grow the rocky material is forced asunder and broken up into fragments. The decay of vegetation adds to the fertility of a soil, because what is termed humus is being formed. This organic portion of the soil consists of the decayed and decaying roots and stems of plants along with

Humus.

the decomposed remains of insect and animal life which has existed in the soil. The fertility of the soil and the maintenance in it of moisture is intimately associated with the presence of a fair proportion of organic matter.

Peat soils.

Some soils, however, are found in nature in which the percentage of organic matter is excessive. Such soils are known as *peats*. The percentage of organic matter in pure dry peat is often as high as 80. By reclamation such land may be made productive. But in its natural state it is surcharged with water. In fact, it probably owes its existence to some interruption of the natural drainage of the district. Clay often underlies peat. It was the pre-existing soil. When the clay soil became water-logged, a condition favourable to the growth of the peat producing plants was induced. This family of plants are known as *Spagnums*. They have one peculiar characteristic. New shoots will grow while the lower extremities of the plants are dying. Thus spungy beds are formed often of great depth, but usually from four to eight feet deep. The reason why peat is found in beds of such depth is that its organic matter has never been brought under the influence of decay. Water fills the pores of peat, consequently the oxygen of the air cannot enter them and therefore the decay or oxidation of the organic matter cannot proceed. In the absence of oxygen other changes of the organic matter have taken place, and unreclaimed peat is in consequence soured and poisoned by an excess of organic acids detrimental to cultivated plants. Peats although common in the higher altitudes and cooler parts of Europe are not usually met with in India. True peats are, however, found in the Neilgherries and the *bheel* soils, or bottom tea soils of Assam are of a peaty character. The *bheel* soils probably owe their origin to the accumulation in the lower valleys of decaying forest growth which has been washed down from the uplands. Unimproved *bheel* soils are found in a water-logged condition. By drainage and tillage these soils become exposed to the action of the atmosphere when the high percentage of organic matter soon disappears through oxidation or natural decay.

Animal action.

Animal action is of some importance in soil formation and particularly in preparing soluble plant food from the mineral matter of an already existing soil. In most countries, earthworms in this respect perform an important function. Leaves, manure or other organic matter are carried below the surface by earthworms and become thus incorporated with the soil. Moreover, the food of earthworms consists of vegetable matter which with the assistance of grains of sand and earth particles, they masticate and digest in their intestines and when the nutriment has been extracted expell the refuse as "castings." These castings may be seen in small heaps at the mouths of the burrows of earthworms. Darwin estimated that 10 tons of fine earthy matter, per acre, annually was brought up to the surface of rich grass lands of England by earthworms and left there as castings. The

Earthworms.

burrows of moles, earthworms, &c., give free entrance to the subsoil of air and water so that disintegration of the substrata is accelerated.

Ants.

In hot climates ants bring up to the surface immense quantities of fine earth to build their hills, and underground tunnels ramify in every direction therefrom. The nests of white ants found in black soil are constructed from *murum* carried up from the limestone bed below. In this way lime in the finest possible state of division becomes to a certain extent mingled with "black" soil.

Volcanic action.

Active volcanoes throw out gases, ashes and lava. Lava soon cracks and pulverizes into a friable fertile soil. The vineyards and olive plantations on the slopes of Mount Vesuvius prove the fertility of recent lavas.

MINERALS OF AGRICULTURAL IMPORTANCE.

Felspar.

Felspar is one of the commonest minerals in nature. There are various varieties. Felspars are essentially double silicates of alumina with lime, magnesia, soda, potash and sometimes iron. The lime and soda felspars are much more easily decomposed than the potash felspars. The chemical action which induces decomposition is not fully understood, but it is known that CO_2 dissolved in water is the chief factor which causes the change. Oxygen probably has some influence particularly if iron be present. Iron silicate would be attacked by oxygen and ferric oxide formed and silicic acid set free. Felspar by decomposition yields a soft white or yellow white substance which consists mostly of the mineral kaolinite which is a hydrated silicate of alumina. Mixed with the mineral will usually be found undecomposed pieces of felspar and also hydrated silica which during the process of decomposition has been set free. The action of the CO_2 may have converted the potash, soda, lime and magnesia into carbonates which are more or less soluble in water containing CO_2, but in existing soils potash and soda are found as silicates to a greater extent than as carbonates. The kaolinite is insoluble in water and like clay which is less pure has a retentive power to hold soluble substances which may have been incorporated with it. Consequently the mineral carbonates named above may, in part, be held by the kaolinite. If much water has, however, had access during the decomposition of felspar, no doubt, the silica, the oxide of iron, the carbonates of lime, magnesia, soda and potash will have been lost and the remnant will be kaolinite or pure clay. This mineral is important as being the foundation of all clay soils. Kaolin, which is a nearly pure form of kaolinite is found in the fissures of felspatic rocks. Water charged with CO_2 has found its way through these fissures and by its action on felspar produced the kaolin. This substance is used in the manufacture of porcelain, china and other fine pottery.

Decomposition of this mineral into soil material.

Quartz. This mineral weathers very slowly.

Quartz is less destructible than any other common mineral. It crumbles very slowly by those weathering influences already referred to. It is not absolutely insoluble. Water containing alkaline carbonates or silicates has a more solvent effect upon it than pure water charged with oxygen and CO_2 only. Pure quartz is silica ($Si. O_2$). At the moment when silicic acid is set free by the decomposition of a mineral silicate it takes a form which is soluble in water. Quartz forms the basis of sandy soils and of those sandstones which are largely quarried and used for building purposes. Silica is considered an essential plant food.

Mica. This mineral not easily decomposed.

Although mica can be easily weathered into minute particles, which as lustrous shaly pieces are observable in many rocks and soils, it cannot be so easily broken up into its component elements. The micas are silicates of alumina with potash, lime, magnesia, iron and manganese. Their decomposition therefore furnishes several of those elements which provide fertility to a soil. They slowly yield clays which may retain some of the potash, the lime and the magnesia dissolved from the original mineral. At the same time the iron and manganese are set free probably in the first instance as the lower oxides of these metals. Exposure to the atmosphere converts these lower oxides into higher oxides. Rust of iron is the higher oxide of iron. We often see sandstone and sandy soils coloured red or brown from the presence of this substance.

Hornblende.

Hornblende forms a considerable proportion of volcanic rocks. It gives a dark green or black colour to trap, basalt, &c. Hornblende and a very similar mineral augite are silicates of lime, magnesia, iron and manganese. The atmosphere and rain-water acting chemically in the manner already described easily breaks up these minerals into their various constituents.

Talc.

Talc is a silicate of magnesia with water of combination. It readily weathers. Like most magnesia minerals it has a peculiar soapy feel.

Zeolites.

Zeolites are silicates of alumina and lime with potash. They are found as crystals in trap and ancient lavas filling up small cavities in the substance of these rocks, and are important because they readily break up under exposure to the atmosphere.

Lime and magnesia. Carbonates of lime and magnesia

Lime and magnesia exist in nature in immense quantities chiefly in the form of their respective carbonates. Dolomite is a compound of carbonate of lime with carbonate of magnesia. Marble, chalk and coral consist mainly of carbonate of lime. Limestones of the sedimentary kind are soft rocks varying in colour between grey, blue or black. They are nearly always impure and usually contain a small percentage of phosphate of lime. Magnesian limestones contain a considerable proportion of carbonate of magnesia as well as carbonate of lime. These carbonates are soluble in carbonated water. The

water from many springs is hard owing to the presence of carbonate or sulphate of lime. Many natural springs contain so much CO_2 that they effervesce when they come to the surface, and such water dissolves large quantities of mineral matters from the rock or soil material with which it comes in contact.

Phosphatic rocks.

Phosphoric acid is largely found in nature as apatite or phosphorite. Apatite is a crystalline and comparatively pure form of phosphate of lime. Phosphatic minerals are usually impure owing to the presence of iron, alumina, also fluorine and silica. The phosphate of lime exists in rocks as tricalcic phosphate which is slightly soluble in soil water. The phosphates of iron and alumina are almost insoluble in soil water, but if present in a soil they are brought in contact with still more active solvents than ordinary soil water.

Clay.

It is noteworthy that clay, which forms a considerable proportion of most fertile soils, is not of itself nutritive to plants. Its use in the soil is in respect of the physical properties which it greatly controls. Clay existing in a soil may be considered a medium in which the necessary plant food is safely stored. To a certain extent humus, sand and lime also exercise physical properties and are more valuable in this respect than in providing plants directly with plant food.

The essential elements of plant food.

An effort has been made to show how soils have been able to obtain some of the elements which are necessary for fertility. Usually with the exception of three or four, all the necessary elements of plant food are present in available form, either in the soil or in the atmosphere in sufficient quantity for the requirements of plants. The essential elements of plant food are :—

Lime. Magnesia. Potash. Soda. Iron. Manganese. Silicon. Sulphur. Phosphorus. Chlorine.	Inorganic.
Nitrogen. Carbon. Hydrogen. Oxygen.	Organic.

PHYSICAL PROPERTIES OF SOILS.

Soils consist of :—

1. An inorganic or mineral portion.
2. An organic or vegetable portion.*
3. Water.
4. Air of the soil.

The effect of heating soil.

If a given weight of soil is heated to 212° fah. the soil water is evaporated. If the soil is heated further, the air is driven off, the soil blackens, sometimes smokes, gives off the peculiar smell of burning earth, and finally assumes usually a red or light colour. The remnant is the mineral portion of the soil. If the soil is fertile this remnant must contain in an available form all the essential inorganic elements of plant food.

The functions of a soil towards plant life.

Soils are intended by nature to support vegetation. The functions of a soil towards plant life are of several kinds. If it is a fertile soil it ought to be of sufficient depth to allow the roots of plants to freely distribute themselves through its substance. (The state of division in which the earth particles exist and the extent of pulverization are of some importance. A lichen will grow on the face of a granite rock. Pulverize the rock to an impalpable powder, and keep this powdered material moist with sufficient rain-water, and it is capable of maturing plants of a much higher order.) This has been proved by actual experiment. It has also been shown that the finer the state of division of soil particles, the more easily do the roots of plants find the necessary nourishment, and the more scope have they to expand their tender rootlets, and to seek after that which they require. The fineness of particles may be excessive as in the case of dense clay. So close do such particles fit that they interfere with the distribution of roots and rootlets, and often with the germination or sprouting of seed. Sufficient porosity and friableness are therefore of extreme importance.

Friableness, porosity and retentive power of soil material.

The atmospheric air should have free access through the pores of the soil, so that it may encourage those chemical changes necessary for the preparation of plant food. Friableness of soil material will also permit free percolation of rain-water, carrying with it dissolved CO_2 and oxygen which will exercise on the substratum those weathering influences which we have already considered. Beyond this rain-water conveys to the soil appreciable quantities of combined nitrogen which has a certain manurial value, and which certain kinds of soil particles have the power to abstract and concentrate upon their own surfaces for the use of plants. In this manner a soil containing a sufficiency of clay and organic matter acts as a filter. Salt water from the sea can be sweetened

* Consisting of humus of the undecayed stems and roots of plants and the larvæ or organic remains of insects.

by passing it through a series of vessels containing nothing but good soil. Sewage distributed over a good loam soaks into the soil, but very little of manurial value is lost in the drainage, not much except pure water escapes, and this is peculiarly the case if a crop is growing at the time. Vegetation seems to enforce this retentive power. The decay of humus or other organic matter is hastened by the presence of air in the soil pores. Humus—a carbonaceous substance, with which is associated much of the nitrogen present in the soil—is thereby subjected to a process of slow combustion. Its carbon enters into combination with the lime, &c., in the soil to form organic acids which may finally be oxidized into carbonic acid gas, setting free the bases with which they combined. The nitrogen is present in the humus in an organic form which as it oxidizes is converted into compounds of ammonia, nitrous oxide and finally into nitrates in which form only is nitrogen taken up by the roots of plants. The conversion of organic nitrogen and other combinations of nitrogen into nitric acid known as nitrification will be discussed more fully by-and-by. At present we wish to emphasize the fact that soil porosity is of considerable importance. Sand and organic matter present in a soil in fair proportion give that degree of porosity which is most desirable. Clay, if present in too great an extent, makes the soil too dense.

Capillarity and the conditions of fertility controlled by this power.

Capillarity is the power which a soil possesses of absorbing moisture on the surface of its particles. If the particles are very minute a greater extent of surface is presented for absorption than when the soil particles are granular and large. Water will freely permeate and percolate through a soil if the pores are large, *i. e.* if the particles are not minute. Water passes through gravel or coarse sand as through a sieve. On the other hand clay unless excessively wet refuses to allow water to escape freely by drainage. During periods of drought or scant rainfall the soil near its surface may get comparatively dry owing to loss of moisture by evaporation, but if there is water in the subsoil at a reasonable depth it may be made to rise within the range of the roots of plants by this absorptive capillary power. A sponge if dipped in water or a lamp wick if dipped in oil soaks up the respective liquids; in the same way a lump of dry clay if dipped in water becomes completely moistened. Different descriptions of soil exercise capillary power in different degrees. Clay or loams rich in organic matter have great capillary power. Sand and gravel are poor in this respect and if the surface layer of any description of soil is in a bad state of tilth, *i. e.*, if the surface soil is consolidated into hard dry lumps of variable size, this upper layer will not be moistened to any appreciable extent by capillary water rising from the subsoil. Seed will not germinate satisfactorily in soil in a bad state of tilth or lumpy condition, because soil particles when thus consolidated are always dry; therefore sufficient tillage of a suitable description should always be given before a crop is sown to secure what in ordinary language is called a favourable seed bed. This means that the upper

layer of soil to a depth of several inches is in a fine friable moist condition. If this upper layer of soil is freely moved by tillage implements at short intervals it is kept in a loose friable condition. The soil particles do not fit close together. The capillarity from the subsoil to the surface is thus interrupted two or three inches below the surface, because the capillary moisture will not rise so readily through the loosened soil particles as through particles fitting closer together. Moisture is thus in a measure conserved and will be found near enough the surface for satisfactory germination when seed is sown. The retention of sufficient moisture to germinate seed and grow a crop is of special importance in a hot country. And in the *rabi* season in order to interrupt capillarity and conserve moisture, which would otherwise be evaporated, it is advantageous to stir the soil between the rows of growing crop until the crop shades the ground. When a crop shades the ground the evaporation takes place from the leaves of the plants, and not to any great extent from the soil. The moisture lost in this manner is replaced through the roots from the subsoil reservoir of moisture below. This during dry weather occasions an upward movement of moisture, which naturally carries with it in solution the soluble salts found in the subsoil, and the roots of a growing crop are in a storehouse whence they probably will get, if the soil is fertile, an abundant supply of plant food. If there is no crop growing, the evaporation continues from the soil surface, and the soluble salts if held in quantity in solution are left at the surface as an encrustation of salt. An encrustation of this kind is found in many parts of India, in some cases causing sterility. This will be referred to in detail further on. In the converse case a continuous and heavy rainfall washes all soluble material out of the soil into the subsoil and beyond the reach of the roots of plants. This explains why crops, during periods of long continued rainfall and absence of sunshine, look unthrifty and become yellow and stunted. Their food has been washed beyond their reach. Under ordinary circumstances we can comprehend the effect of a continuous circulation of water in the soil. We can understand how the downward current of rain-water, charged with carbon dioxide and oxygen, and the upward flow of capillary moisture, create chemical actions, which have a solvent effect on soil material whereby much plant food is prepared. A soil capable of causing this action is a most valuable one.

Hygroscopic action.

Hygroscopic action is the power of a soil to absorb moisture directly from the atmosphere when the air is moist. This power is hardly possessed by sands, but to a considerable extent by clays, loams and soils of a vegetable character, particularly the latter. During the heat of the day in India much moisture is lost by evaporation from soils. The air not being easily saturated absorbs this moisture readily. The evaporation causes the soil to cool. If the soil is of such a character as will freely admit air into its pores the water lost by evaporation during the day may be recovered in part by hygroscopic action at

night if the soil particles have good hygroscopic power. Loams and particularly such as are well manured and rich in organic matter admit air more freely than clay and absorb more hygroscopic moisture. Limestone soils like sand have poor hygroscopic power.

Shrinkage when dry and increase in volume when wet, are more noticeable in some descriptions of soils than in others. Pure sand can only hold some 10 per cent. or less of moisture when wet, whilst clay soil may hold 30 per cent., or if dense even more. Loams especially those containing a fair percentage of organic matter can hold a considerable percentage of water when saturated, but as they dry they shrink or contract in a different manner from dense clay. Black cotton soil which is a dense clay owing to the adhesive plastic character of its particles contracts in sections so to speak. Fissures or cracks form at internals of one, two or three feet. The surface of black cotton soil or any other clay soil in India presents in the hot weather a net work of wide gaping cracks or fissures. These cracks extend three to six feet towards the subsoil and are generally 2 to 6 inches wide at the surface, but narrower below. The presence of these cracks admits air freely to the subsoil and through the soil proper, and thus thorough airation and exposure are beneficial, but the successive cracking ruptures the roots of trees and other vegetation, and on this account is harmful. If there is an admixture of sand in clay the soil becomes a loam, and although this class of soil does contract during the dry weather the shrinkage is not so observable as in dense clays. The particles are not so adhesive and plastic, therefore the lines of separation are more numerous and not so wide. A loam will therefore experience the benefits of shrinkage, *i. e.*, the thorough airation which the soil and subsoil thereby enjoy, but at the same time will not fissure to the extent which will cause injury to the roots of existing vegetation. The presence of sand or lime or humus in due proportion in any soil obviates the tendency of the clay particles to consolidate and of the soil to crack or fissure injuriously. Shrinkage.

An adhesive soil is one that is in popular language termed heavy or difficult to work. The preponderance of clay determines to a considerable extent the degree of adhesiveness but the state of dryness has a considerable influence also. Any ordinary observer may see how difficult it is to plough or dig soil that is wet. The earth particles not only adhere closely together but also stick tenaciously to the implement used. A certain degree of adhesiveness is a valuable quality, but when due to a swampy waterlogged condition it is undesirable even in the lightest description of land. Sandy soils, lime soils and vegetable soils in an ordinary state of moisture have very little adhesion. The power required to plough such land is much less than that required if the same description of land is surcharged with water. Clay land which is naturally or artificially well drained, if subjected to seasonable tillage, acquires a fine state of tilth, in which condition its parti- Adhesiveness.

cles, if dry, have hardly any more consistence than sand. But only a few inches in depth of the surface of a clay field is ever in this condition. Below this layer the soil is soft and plastic when moist, or hard and baked when dry, and offers great resistance to the implements used in tilling it. Draining and subsequent deep ploughing obviates the difficulties of adhesiveness in the most stubborn clays. But the most reliable way of ameliorating this condition in India is a difficult problem, because that which makes a soil adhesive also enables it to retentively hold moisture, which property in India is a most important and valuable one.

Temperature of soils and the conditions affecting it.

The temperature of the soil, although mainly influenced by the climate and the mean temperature of the air, is also affected by the material which constitutes the soil, by the colour of the soil and its aspect or exposure. In the same district a farmer will class one soil as warm and another as cold. The chemical changes induced by the decay of the vegetable matter in the soil give rise to a good deal of heat, which is most observable in porous soils, through which air and water can freely circulate: but this heating which is due to oxidation can only take place when the soil is sufficiently warmed by the heat of the sun. Black or dark coloured soils get hotter than the air during the day, but will get quickly cooled by radiation during the night, which with a clear sky induces the deposition of dew. But the effect of colour is only appreciable while the seed of a crop is germinating or before the crop completely shades the ground. Black soils are sooner warmed than those of a lighter colour, excepting light coloured sands which absorb heat quickly; because sand particles are good conductors of heat and such soils get very hot to a considerable depth and sometimes become sterile on this account. All soils when thoroughly wet are about equal in their absorptive power for heat. Water is a poor conductor of heat. Water filling the pores of the soil interrupts the conduction of the heat of the sun's rays into the body of the soil. The heat is expended in evaporating the stagnant water of the soil and the soil itself remains cold. The student may satisfy himself that evaporation requires heat by pouring on the palm of his hand a little ether or any volatile oil. As the oil volatilizes a sense of coldness is felt. Slope or aspect is of importance in cool and temperate climates. The northern slope of a hill is some degrees colder than the sunny southern exposure. The reason is that the sun's rays are more concentrated in the latter. In temperate and cold climates, the border under a wall with a southern exposure is that part of a garden where early vegetables are grown.

THE WATER IN THE SOIL IN ITS RELATION TO PLANT LIFE.

Plants exhale moisture and require water for their structure.

Plants have not the power to absorb moisture from the air. A moist atmosphere, however, prevents them exhaling moisture as rapidly as in a hot sun.

Many plants exhale many times their own weight in a very short period. Evaporation through a plant must be replenished at the root by continual absorption, otherwise the plant withers and dies. Not only so, but water is itself a plant food. 75 per cent., often a higher percentage, of the weight of succulent plants consist of water. Moreover, the great bulk of the dry structure of plants consists of carbon united with oxygen and hydrogen in the same proportion as the latter elements exist in water; and it is believed that water in the chlorophyll cells of the leaves in the presence of light, potash, magnesia, and iron combines with the carbon, which is either directly or indirectly derived from the carbonic acid gas of the atmosphere and forms sugars which are circulated through the plant and converted into starch and other carbo-hydrates and go to form the structure of the plant. Exhalation of moisture proceeds most rapidly in hot dry windy weather, and this is the time that it can be least spared, therefore such weather is trying to plants. As a general rule the roots of plants absorb more moisture when the soil is warm than when it is cold, one reason being that growth is then more vigorous. But apart from this plants subjected to a degree of cold, whereby the temperature is scarcely above the freezing point, have been known to droop simply because their roots had not the power to absorb an amount of moisture from the soil equivalent to that evaporated through their leaves. In temperate climates, the mean temperature of the different seasons is widely different. There is a dead season—winter—when plant life is inert and no moisture is absorbed. Spring follows and the genial warmth reinvigorates vegetation, awakens plant life from a dormant state, sap begins to circulate in trees and other perennial plants, and soon the summer foliage is produced. Plants transpire water through the stomata or pores on the leaf. It is a curious provision of nature that these pores should partially close like valves when the air is very dry, and when an unchecked amount of transpiration would be alike hurtful to the plant and to the soil. Undue transpiration of water is not necessary to the healthy growth of plants. In fact when the air is moist, and when transpiration is at its lowest pitch, plants make a healthy vigorous growth.

The percentage of water in vegetation is affected by soil and climate.

The percentage of water in vegetation is influenced by that in the soil and there is a degree of moistness which is suited to produce the best results. At the same time it should be observed that different families of cultivated plants thrive best in soils of different degrees of moistness. In a general way it has been observed that plants grown in a soil in high manurial condition and forced—so to speak—have succulent watery tissues, and not the same percentage of dry organic matter, as plants of the same crop grown on similar land not so highly manured. The percentage of water in plants grown on a dry limestone or sandstone soil is less than that of similar plants grown on a moist loam. It is a well known fact that grass grown in a wet summer, will have greater bulk, and weigh more than grass grown in a

dry summer. But if each quality be made into hay, the percentage weight of hay from the latter is much greater than that from the former. This fact is practically known to farmers; for their experience tells them that grass, the produce of a wet season, although it appears succulent and green, has not the same nutritive value as the same weight of grass grown during dry weather.

Weight of soils.

The terms heavy and light as applied to soils have no connection with their actual weight, but only to the ease or difficulty of working them with tillage implements. The terms heavy and light are respectively applied to clays and sands; but if the actual weight of the same volume of each be taken as the test the terms would be reversed.

The air in the soil.

The air in the soil is usually poorer in oxygen and richer in carbonic acid gas than the atmosphere, while the proportion of nitrogen is common or equal in both. This is not difficult to explain. Nitrogen in its free form is an inert or inactive element in the soil. It is simply there, because it must enter the pores of the soil as part of the atmospheric air. Oxygen is continually used in forming oxides in the soil. In the decay of organic matter oxygen is used; and carbon dioxide is an indirect product. This is one reason why the proportion of oxygen is diminished, and carbonic acid gas increased in the air of the soil. The air of a recently manured soil contains very little oxygen but a very high percentage of carbonic acid gas; because the organic matter of the manure has rapidly undergone decay or oxidization. Not only is the organic portion of the soil oxidized, but any oxidizable material in the soil also—the lower oxides of iron, manganese, &c., are converted into the higher, &c. In a recently manured soil carbonic acid gas has been found to exist in the air of the soil in varying proportions, from 10 times to 390 times the usual proportion in the atmosphere. Rain-water loses its carbonic acid gas as it soaks through a soil. The carbon dioxide is used in converting mineral oxides, into carbonates. The air of the soil is continuously undergoing change. The oxygen utilized in oxidation is replenished from the atmosphere; while the carbonic acid gas indirectly generated by the decay of organic matters is in part diffused into the atmosphere as it is formed, and the leaves of a growing crop are thus fed by air containing a higher percentage of carbonic acid gas than that which we breathe. This remark is in reference to a crop grown on land recently manured.

SUBSOIL.

Immediately below the soil and between it and the stratum of unweathered rock, is the subsoil. Often no distinct line of demarcation divides the soil from the subsoil, the one gradually merges into the other. The subsoil never having been stirred by tillage is generally more compact than the soil and often of a different colour. Its component particles, if granular, are

coarser than those forming the substance of the soil. Moreover, it contains only a small percentage of organic matter, that being the remains of the roots of plants that have extended down so far.

Good and bad subsoils.

Subsoils are of importance because they form a reserve store from which the waste, caused by the annual growth and removal of crops, is partially replenished. A good subsoil is one, that by gradual disintegration produces soil material, which does not lower the physical properties of the surface soil. It will permit free natural drainage, but at the same time, conserve the elements of fertility from waste by drainage that is too free. A substratum of alluvial deposit would form the best possible subsoil. Limestone is good if the soil itself is deep. *Murum* underlying black cotton soil at a reasonable depth of say 3 to 5 feet is a good subsoil. It ensures that amount of free drainage during heavy rainfall which black soil requires. It is unusual to find a deep soil overlying a hard rock, unless it has been transported because hard rock weathers so slowly. We find an exception in favour of Deccan Trap and all recent lavas which soon weather into soils of considerable depth. Gravel and sand in deep porous beds immediately underlying any ordinary soil are undesirable. A subsoil of this class makes the term "hungry" as applied to a soil appropriate. Yet a bed of clay of moderate depth overlying gravel is by no means a bad combination. The clay has within itself the means of recovering that fertility, which is lost by the removal of crops, and the underlying gravel secures a certain degree of natural drainage. It may be laid down as a maxim that any impervious layer underlying a soil will materially lower the productive capabilities of the land, for, free circulation is thereby stopped both of air and water. Heavy dense clays are often unsatisfactory in this respect unless they are artificially drained. The accumulation of water in excessive degree in the soil is often caused by an impervious subsoil and although nothing is so essential in the cultivation of our fields, as an adequate supply of moisture, nothing is so disastrous to ordinary crops as the immersion of their roots in stagnant water. The waste of soil material caused by drainage and otherwise may be made good by the disintegration of the subsoil which action is accelerated by deep tillage.

It is risky to mix the subsoil with the soil.

Deep ploughing can do no harm if the implement used stirs and breaks up the soil without incorporating the loosened material with the surface soil. The ordinary native plough acts in this manner if it goes deep enough. It is risky to mix the subsoil with the soil, because there are often present, particularly in clay subsoils, certain unoxidized ingredients which are poisonous to vegetation.

CLASSIFICATION OF SOILS.

The proximate principles of soils.

The proximate principles of soils are sand, clay, lime and vegetable matter. The relative fertility of soils largely depend upon the proportion in which these constituents are mixed together.

Sandy soils.

A soil in which sand largely predominates is called sandy. A soil of this class would be of low agricultural value. Pure sand is perfectly sterile. Although only useful to a very limited extent as a plant food, a due proportion of sand gives to our agricultural fields, certain qualities that are invaluable. The texture of a soil greatly depends upon the proportion of sand it contains. Friable soils, and such as are easily worked, contain a certain proportion of sand. Such soils permit a free passage of air and water through them. Sandy soils are warm, a point of material importance in cold and temperate climates, but rather detrimental in hot countries. They are called light soils in contradistinction to clays, which, because they are difficult to plough, are called heavy. Sandy and gravelly soils are undesirable in any country, but particularly in a hot climate, when the proportion of sand or gravel preponderates in a pronounced degree. They are easily affected by drought. A sandy soil would contain less than 10 per cent. clay and more than 80 per cent. sand.

Clay soils.

Clay soils are termed argillaceous. Pure clay is as sterile as pure sand, but seldom is found in nature. In fact usually we may reckon upon clays being fertile, and they usually continue so, because they are capable of conserving what they contain. Clay soils are dense and are difficult and expensive to till. They are plastic, *i.e.*, they are soft and glutinous when wet, and harden when dry. They must be cultivated with a good deal of judgment. If ploughed in a wet condition and exposed to the sun afterwards, they bake and harden and become difficult to reduce to a fine state of tilth. In India, rain falling on a hardened lump of clay soon softens it. In Europe frost exercises the same effect. Clays are retentive of manure and moisture. They usually contain fair proportions of potash, lime and magnesia, because they owe their origin mainly to the decomposition of felspathic rocks which contain these substances. In temperate and cool climates drainage is essential to make them fertile—not necessarily so, in hot countries. The deep black soils of India which are essentially clays may, during heavy rainfall, appear surcharged with water; but if the soil does not become actually swampy, the water which appears to be excessive for the time being may prove most valuable later in the season when there is usually a scant rainfall. There are, of course, situations where the necessity of artifical drainage for such land is evident even in India. Heavy clay when moderately moist can be squeezed in the hand into a plastic mass, a lighter description of clay of the same degree of moistness would have a tendency to crumble rather than to be moulded into a definite shape by the hand.

Heavy clay soil.

Soils that we are accustomed to class as heavy clays might be constituted thus:—

85	per cent.	clay.
10	,,	sand.
2	,,	lime.
2	,,	humus.

A lighter class of clay soil is one that contains more sand and less clay. All clay soils contain over 50 per cent. clay.

Limestone soils are called cretaceous or calcareous. They contain over 20 per cent. lime. They are found to vary very much in character and are usually light, that is, easily worked. The greater proportion of them are poor thin soils having a low standard of fertility. Lime has the power to make clay less tenacious and sand more adhesive and is an essential plant food and an important manure. Limestone soils.

A soil rich in humus or organic matter is called vegetable. Such soils vary from the rich garden mould containing about 10 per cent. humus to the poor peat containing as much as 80 per cent. vegetable matter. The rich dark brown colour, which liberally manured garden land acquires in temperate countries but not in India, is due to the humus it contains. This organic substance will make a sand more retentive, a clay less so. It is seldom present in limestone soils in a high percentage, because lime hastens its decay. Vegetable soils.

A loam is a mixture of clay and fine sand, and usually contains a higher percentage of organic matter than clay does. A soil cannot be called a loam, unless sand is present in sufficient quantity to make it friable and easily tilled. Loams may be sub-divided as under :— Loams.

	Clay Loam.	Loam.	Sandy Loam.
Clay ...	...40 to 50 per cent.	30 per cent.	20 per cent.
Sand ...	...50 to 40 ,,	65 ,,	75 ,,
Lime ...	... 2 ,,	2 ,,	2 ,,
Organic matter...	2 to 3 ,,	3 or 4 ,,	2 ,,

Loamy soils are much esteemed. They have sufficient retentive power to hold manure and moisture. They contain or might contain all the elements of fertility. They may owe their origin to alluvial deposit. They are usually naturally well drained and are capable of growing any description of crop. They are warm soils often of considerable depth and consequently not easily exhausted.

Marls are soils that contain more than 5 per cent. and less than 20 per cent. lime. They are classed usually as clay marls, loamy marls and sandy marls, the first named being the most common. Marls are of sea formation. Shells and other remains of shell-fish are characteristically present and doubtless this accounts for the presence of phosphoric acid in quantity sufficient to give some marls a considerable manurial value. In Great Britain marls are found in bed deposits often at a considerable altitude. These are dug out and carted considerable distances to be applied as manure. Marls.

Alluvial soils are fresh water or river deposits. Soils of this class are found fringing the courses of many streams, particularly at points where their Alluvial soils.

flow is slow. Alluvial soils are often of considerable depths and usually partake of a loamy character, being formed by the deposition of denuded material brought down from the upper reaches of rivers. This material being ordinarily of a mixed character, there is every probability that the resulting soil will contain an abundance of the elements of fertility. If such soils are subject to flooding once a year or oftener, then their fertility can hardly be impaired by continued cropping, because a periodical deposit of fine mud or silt adds to their productiveness and makes them independent of manures. The best meadow or hay land in England is of this class ; so also is the *bhátha* lands of Gujerat in the Bombay Presidency.

SOILS OF THE BOMBAY PRESIDENCY.

Throughout the Bombay Presidency soils that vary from each other in colour, texture, and otherwise are each known by an appropriate name. Undoubtedly the vernacular term applied to denote the character of a particular soil conveys to the mind of a practical cultivator significant information regarding the intrinsic value of the soil, as regards the manner in which it should be tilled and the crop or crops which it will grow best.

Deccan upland soils very variable.

Throughout the Deccan the soils vary to an extraordinary extent in character and in productiveness. On the slopes and uplands of the low trap ranges, the soils are thin and poor. The disintegrated trap furnishes an *in situ* soil, which is usually light coloured, and which is moderately productive only in years of favourable rainfall. In years of scant rainfall the cultivator obtains from it a precarious living. Usually the lowlands have darker coloured deeper soils which are doubtless annually increased in depth and are fertilized by washings from the higher levels. Within the limits of a small field, however, soils of totally different character are found and this is almost impossible to account for. In the Deccan the Survey Department takes cognizance of this fact by insisting on each field being tested in numerous places when the soil is being classed. Elsewhere in the Presidency this is not so necessary ; and in some districts, especially in Gujerat, the soil is so similar throughout whole districts that one test hole dug in a field is sufficient to determine the character of the whole field, sometimes of a whole village or district. In parts of the Deccan as for instance in the Parner Taluka of Ahmednagar, and Karmála in the Sholápur district numerous rounded stones of variable size are found in almost every field. The soils in which these stones are found are comparatively fine in texture, light in colour in the uplands but darker and fairly fertile in lower situations. Stones brought up by tillage implements are thickly scattered over the surface. The larger stones are used for boundary marks and to construct low dikes or walls round the cultivated areas. These stones found scattered through the soils, if examined, present a rounded shaly surface and show every appearance of rapid disintegration through the action of weathering influences.

Soils less variable in low lands and open plains.

Stony soils.

The Deccan black soil plains.

In the districts of the Deccan which are remote from the foothills of the Gháts there are black soil plains where the character of the soil is less variable. The wheat lands of Kopárgaum in Ahmednagar, the *rabi jowàr* lands of other *tálukas* in Ahmednagar, in Sholápur, and Bijápur are of this class ; also the cotton and *jowàr* lands of Násik and Khándesh. In the latter district this black soil grows cotton as a staple crop and this crop would be the staple in other districts of the Deccan on similar land if the rainfall of such districts suited the crop. Bijápur, Sholápur, Ahmednagar are districts chiefly dependent on *rabi* rain, therefore in these districts cotton is but sparingly grown on soil which is commonly known as black cotton soil. Underlying these comparatively level tracts of black cotton soil *murum* is usually found at a depth of 18 inches to 4 feet. This *murum* overlies trap rock and is shaly, impure limestone so soft that its upper layer will yield to a pick. The *murum* layer is no doubt trap partially decomposed and impregnated with lime washed down from the upper soil probably dissolved in soil or rain-water and deposited in the shaly subsoil. Below the *murum* layer harder pure trap is generally found. Trap rock is believed to be the parent of black soil proper. The rich wheat lands of Kopárgaum and of the Godávari basin and the deep black soil which fringes the Tápti throughout the whole length of Khándesh in belts two to three miles wide on each side of the river, also the rich deep soil of the Krishna valley, though similar in character to black cotton soil, are too deep and two retentive of moisture in the monsoon for the successful cultivation of cotton, and such soil is best adopted for *rabi* crops of *jowàr* wheat or gram. In Khándesh linseed is also extensively grown on this description of soil.

Light soils of the Deccan and Southern Maratha Country.

Various soils described and vernacular names given.

Throughout the Poona, Násik, Khándesh, Sátára, Ahmednager, Sholápur and Bijápur Districts there is in almost every *táluka* extensive areas of light upland land, some so poor and shallow that it is unsuitable for cultivation and grows little but spear grass. In more favourable upland situations the soil where cultivated is shallow red brown or light coloured which owes its origin purely and simply to the disintegration of trap, the characteristic red or brown color is due to the oxidation of the ferrous compounds which Deccan trap contains. Soil of this class is called in the Deccan *barad* or mixed. It contains numerous desintegrated fragments which tend to keep it open and make it more liable to the disastrous effects of drought. In the lower valleys of the trap foothills and in the lower situations of broken undulating districts the surface soil is generally mixed black locally termed *madhyam káli*. This soil is generally 2' to 3' deep. It has a substratum of *murum*. It is mixed with nodular pieces of limestone and small fragments of disintegrated trap. The subsoil water is generally found at a depth of some 25 feet. This kind of soil if well tilled and sufficiently manured grows under well irrigation all kinds of garden crops in

quick succession. In valleys with this description of soil large trees freely grow, the most common being, perhaps, mangoes, tamarinds and *bábhul* (Acacia Arabia). But in the black soil plains where wheat, gram and *rabi jowár* are grown large trees are rare. They do not thrive because the soil freely fissures or cracks in the hot weather thus exposing and rupturing the roots of young trees. If, however, once fairly established mango trees will continue to thrive, but when young require attention. Mango topes where they exist may be protected by ploughing the land round and near them. Throughout the eastern plains of Dhárwár and Belgaum the soils are mostly black, mixed black or *barad* according to situation. *Pándhri* is a light coloured soil found locally in the Deccan. It is naturally poor; but under irrigation and helped by manure, it becomes productive. Soil of this class is generally selected for the village site, probably with a certain amount of wisdom. Its natural drainage secures sanitation of a sort. *Bhurki* is a light coloured soil overlying a salt substratum called *kharan* and is capable of producing good crops of *kulthi* (Dolichos uniflorus), *tili*, *bájri* and some other light land crops. The *kharan* or salt substratum often crops out and is often seen on the banks of rivers and smaller streams, and is in local request, because, being impervious to rain or moisture, it furnishes the material used as an outer layer on the roofs of the flat roofed huts of villages in Khándesh. *Mand* is a light coloured earth found croping out on banks of streams or *nalas* and is that substratum which because impervious to moisture, is suitable for those underground pits or *peos* in which grain is so extensively stored.

Gujarat soils.

The soils of Gujarat are classed under three main divisions :—by Beyts.

(1) *Káli.*—The black cotton soil.

(2) *Gorádu.*—A deep alluvial soil of decidedly sandy character.

(3) *Goramti.*—A light or red coloured clay loam which although found in the various parts of the province is, compared with the two other classes, of limited area.

Black soil.

Extensive tracts of black cotton soil are found in Broach and Surat. The same description of soil is found on the Kathiawar side of the Gulf of Cambay, and it has been conjectured that the Gulf of Cambay was once also a black soil plain. By denudation or more probably by submergence the sea encroached. The black cotton soil plains are usually comparatively level and situate below the general elevation of *gorádu* and *goramti* soils. *Káli* is supposed to owe its origin to alluvium brought by the Tapti and Nerbudda rivers from the extensive trap regions of the Central Provinces. Several theories have been promulgated to account for the persistently black colour of these cotton soils. The colour is not due to the presence of a high percentage of organic matter as has sometimes been sup-

posed. Nor does there appear to be any sound foundation for the theory that the soil particles are dyed black by organic salts of iron. Dr. Leather claims that he has solved the problem. He says that *regar* or black soil proper, contains a dark coloured mineral peculiar to this soil. When *regar* is boiled with concentrated sulphuric acid the insoluble residue is very dark brown. Other kinds of Indian soils similarly treated yield insoluble silicates which are either white or red with a small proportion of the black brown silicates characteristic of black cotton soil. The original soil material carried by the Nerbudda and Tapti rivers from the trap regions which they drain has probably been modified by tidal, if not by sea, action. Pure black soil is distinguished by the term *regar*. It is a clay or clay loam free from stones and pebbles, but with small nodular pieces of lime and when deep is practically inexhaustible. Underlying *regar* is a deep bed of yellow white earth comparatively easy to dig and consisting of clay, lime and sand intimately mixed together. Sometimes very impervious, but sometimes the proportion of sharp sand gives this subsoil more pervious qualities. In pure *regar* this subsoil is rarely reached at a less depth than 5 or 6 feet. Any divergence in colour or texture from *regar*, relegates a soil to a subdivision and gains for it an appropriate local name.

Sub varieties black soil.

Káli-khokhar is a greyish black soil with the same subsoil as *regar*. It has lime nodules mixed freely through it. When wet it is sticky and difficult to work; when dry it cakes and fissures to an excessive extent. *Káli-bara* is more friable than true black soil. It is brown in colour and is often impregnated with salt. *Káli-besar* is a dark brown soil found at a higher elevation than *regar*. Pebbles are intermingled through it. Although not directly in contact with trap, its proximity to this rock indicates that to some extent it may be of purely local formation. It can be irrigated to advantage and for this reason is more valuable than pure black soil. All black soils crack freely and when dry are very difficult to plough.

Kiari.

The term *kiári* as applied to a field has no reference to the description of soil, but rather because the field is embanked to impound water for rice cultivation. The soil may practically be of any depth and of any colour. For successful rice growing it should contain sufficient argillaceous matter to be retentive of moisture. The position of a rice field in respect of the facility with which the drainage water from surrounding higher land can be collected and impounded, is of more importance than the character of the soil.

Goradu soils.

Gorádu soils are in Gujarat characterised by immense depth. They are distinctly sandy in character, varying from the drift sands of the Ahmedabad district to the rich loams of Kaira and of many villages in the Baroda Territory. *Gorádu* soils are entirely alluvial and have probably been formed from primitive and matamorphic rock detritus brought down from the regions now drained by the Máhi and Sábarmati rivers. *Gorádu* proper varies

in consistence as well as in colour; the latter may be any shade between a light fawn and a rich brown. When *gorádu* has a decided proportion of clay it becomes more distinctly a loam and the term *besar* is applied. The usual presence of alkaline salts either in the soil or in the subsoil water makes this class of land specially adapted for tobacco cultivation. Both *gorádu* and *gorádu besar* when once set in the fair season are difficult to penetrate with any tillage implement.

Bhátha soils.

Bhátha is a red, brown or chocolate coloured soil found high and (except during flood) dry on the shelving banks of rivers. It is alluvium deposited by the water of rivers in flood, and if submerged as it periodically is by flood water, receives from time to time an additional deposit of alluvium which adds to its fertility and depth. It is found in extensive belts along the banks of the Tapti and Nerbudda in Surat and Broach. When it is of the first class its soil particles are in the finest possible state of division. Sometimes the rivers bring down sand a deposit of which lowers the fertility of *Bhátha*. The best description is a free working loam of great depth capable of growing without irrigation certain garden crops. Subsoil sweet water is generally got at no great depth and when necessary *kacha* wells are sunk at small cost. These have to be renewed annually, but the cost is very trifling. Castors (Ricinus communis) and tobacco (Nicotiana tabacum) grow magnificently on *bháthu* land without irrigation. Old *bhátha* soils are sometimes found inland and at considerable distance from existing rivers. They are termed *gorát*. Where such soil exists, it is classed by the surveyor as superior order soil; or when as is generally the case sweet water is at moderate depth as "Natural Bágáyat" or "garden land." The inexhaustible character of its mineral matter, which is of uniform texture and colour to a great depth, and its friable loamy character make it specially suited for irrigation. With an ample supply of manure it can be irrigated continuously. On Natural Bágáyat land the finest garden crops such as, sugar-cane (Saccharum officinarum), ginger (Zingiber officinale), turmeric (Curcuma longa), potatoes (Solanum tuberosum), garlic (Alium sativum), cabbages (Brassica oleracea), and numerous other vegetables can be raised in rapid succession. The soil does not bake and harden when dry. In fact it gets no time to do so and when wet has no tendency to stickiness.

Gorát soils.

Goramti soils.

Goramti is not alluvial. It is formed *in situ* from laterite rock and is a ferruginous clayey soil, red or yellow in colour. It is adhesive owing to the presence of clay and lime in undue proportion and is rather intractable to work. *Goramti* is characteristically seen at Párdi in Surat. Sometimes it is called *gorát* for no better reason than that it resembles *gorádu* in colour.

Natural features of the gorádu and black soil tracts.

In passing from a black soil to a *gorádu* tract, the difference in the natural appearance of each district becomes strikingly apparent. The cotton plains of Surat and Broach are more or less treeless; the site of a well, the

location of a village or the position of an elevated strip of garden land are marked by the presence of trees of fair size. In *gorádu* soils, the characteristic features are hedgerow, timber trees of grand proportions, and impenetrable cactus hedges surrounding every field. The deep wells have a never failing supply of water, but salt and sweet wells are alike common. Alkaline water may be found in one well, whilst in another only a few yards away the water may be perfectly sweet.

In the Konkan the soils are divided into three principal groups, namely, (1) *Rice*, (2) *Garden* and (3) *Varkas*. Konkan soils.

There are many varieties of rice land. The open tracts of rice land which are found in the bottom of the numerous valleys are called *mali* soils. There the surrounding rock is laterite. The *mali* soil consists of ferruginous clay and is consequently stiff and difficult to work. The colour varies from yellow-red to dark brown. More inland as the Gháts are approached and where trap rock begins to crop out the *mali* soils are darker in colour, more friable and of greater depth. *Mali* soils usually retain sufficient moisture to grow a second crop of *vál* or some other pulse. The higher lying rice soils found at the base of the hills or on the terraced slopes vary in character, but are usually lighter than *mali*. *Khárvat* is the term given to lands reclaimed from the sea either directly from the ocean or along the banks of tidal creeks. The tide is driven back by embanking the land to be reclaimed which for a series of years contains salt and is capable only of growing coarse or salt rice at first.

The conditions necessary to class land as garden land in a track of heavy rainfall are, a light easily worked soil, and sweet well water. The stretches of richly cultivated gardens fringing the coast in the Máhim and Bassein Tálukas of the Thána District are good examples. The soil here is of a light sandy character. No other description of soil would bear tillage for garden crops during the heavy monsoon rainfall. With the aid of heavy applications of manure—particularly of castor cake—this soil bears magnificent crops of betel-vine (Piper betel), ginger (Zingiber officinale), sugar-cane (Saccharum officinarum) and plantains. The wells are not deep, and the water is very shallow in them. For this reason the only water lift used is the Persian wheel. Garden land.

These lands occupy the uplands of the Konkan. The coarse hill millets, *nágli* (Eleusine coracana), *vari* (Panicum miliacum) and *harik* (Paspalum scrobiculatum) are generally raised on *varkas* land, which is classed as of two sorts. The more level parts where the plough can be worked to advantage is called *mál-varkas*, whilst the steep slopes which can only be tilled by hand implement are termed *dongri-varkas*. *Varkas* land is allowed to be waste periodically to recover fertility. A short rotation of crops is followed by a period of rest. Before being brought again under tillage, the growth of scrub Varkas lands.

jungle and grass which meantime grows is cut and laid over the surface and burnt. The system of cultivation by hand implement in these patches of cultureable land is known as *kumri* or *dalhi* cultivation.

Soils and agricultural features of the Southern Maratha Country.

Satara soils.

In passing through Sátára, Sángli, Miraj, Chinchli, &c., the soils met with are fairly representative of those found generally throughout the Deccan. There are the bare uplands with rock at or near the surface and growing mostly spear grass. The low hills are stony without much scrub or forest growth. In the valleys and lower grounds the soil is black or medium black of moderate depth with *murum* or trap as the underlying stratum. *Rabi jowári* with subordinate safflower are the most common crops in such land. The other crops, both dry and irrigated, are similar to those grown in the black soil parts of the Deccan. Dry crop patches of chillies, also of tobacco, are very common. Then on higher situations the soils are thinner and lighter coloured, often being red or light brown and stony. Wells are fairly numerous in the lower lands, and patches of the usual crops under irrigation are common. In the lower lands of fair depth *bábhul* and other trees are numerous, but they have been lopped so often that they present a ragged unthrifty appearance.

Geological formations and soils of the western parts of Belgaum and Dharwar.

In the west of Belgaum and Dhárwár the country changes. The hills are covered with forest growth, the lower-lying valleys are fertile and well cultivated. In the forest area in favourable situations the clearings are terraced into rice beds with great ingenuity. The soils have originated from laterite, and are ordinarily clay-like in consistence and yellow, red or reddish brown in colour. The railway and other cuttings show great variation in the character of the substrata. These strata for a considerable depth show decided appearances of iron ore which, no doubt, gives the characteristic colours found in the soils. The general formation has much the appearance of boulder earth. In some cases rounded stones and boulders are concreted amongst finer material. In other cases the section of a cutting shows concreted gravel. Often the whole stratum is of much finer consistence and very light coloured—usually a dirty yellow. Below the boulder earth and sometimes cropping out at the surface there appears to be ferruginous limestone in cleavage beds. The stone is somewhat like yellow freestone. It is quarried in slabs or flat blocks and makes useful building stone. All these formations weather rapidly into soil material.

The soils of the valleys and the uplands.

The bottom soils got from these formations are dull red or brown in colour and of considerable depth. They are clay loams of great natural fertility. The higher lying lands are lighter in colour, and within small areas sometimes vary considerably in consistence and colour. The poorest soils are those which are lightest coloured.

Kanara soils.

Surface soils and substrata of much the same character are found in above ghát parts of Kanara. The virgin soils of the lower dales are

deep and rich as evidenced by the luxuriant tangle of forest growth. The *kan* or evergreen reserved forests are found in such situations. Trees of magnificent proportions are there found. The dense undergrowth is well nigh impenetrable. These bottom lands where cleared make excellent rice lands and betal palm and spice gardens. In most upland Kanara lands the forest growth is less vigorous. Everywhere ferruginous stone crops out, and is largely used for road metal. Rounded pebbles or stones of flint like limestone are also found mixed with the red or red-brown earth near the surface. These when broken make excellent angular road metal. Sometimes not far from the surface particularly on hill sides blue stone is found which can be quarried in long flat slate-like slabs. Sometimes it is less shale-like and long pieces can be quarried which when dressed or shaped make excellent gate posts, and as such are used through Kánara and the west of Dhárwár. The ferruginous stone is often not solid in structure being full of cavities. Such when found in flattish square pieces is used as a durable building stone. The mortar fills the cavities, and solid substantial walls are constructed.

Some of the agricultural features of the Southern Maratha Country.

In Belgaum and Dhárwár the crops grown depend to some extent upon position and rainfall. On fairly dry naturally drained situations *jowár* is extensively grown and to a less extent cotton. Mango and other good shade trees are numerous on this class of land. The mango trees are grown from seedlings planted rather wide apart in straight rows and the ground between the trees is cultivated with ordinary dry crops. On lower lying deeper soils rice is the chief crop and the fields are embanked with small embankments and where necessary terraced. The area of a particular rice field is on an average larger than usual. The rice is invariably drilled and with it a decided sprinkling of *jowár*. This is not a common mixture elsewhere. The vale of Belgaum has a very extensive rice area of this class and second crops of *vál* and various gourds, cucumbers and melons are grown after rice on the outskirts of Belgaum City, and generally in its neighbourhood numerous garden crops are grown under irrigation on the rich red-brown soil. These crops grow with great luxuriance and are taken in rapid succession. In the rice fields of Belgaum and Dhárwár sugar-cane is occasionally grown. The sugar-cane can easily be detected at almost any stage of growth, because when this crop is grown the particular field is protected by a wattled hedge which readily catches the eye. In descending from the foothills of the Gháts towards the plains of Dhárwár the same kinds of soils as prevail in western Belgaum still continue with much the same variety. Rice is the staple crop. Throughout the whole of the red soil area in Belgaum and Dhárwár large trees, giving excellent shade, grow freely in most fields and the district has for this reason a very well sheltered appearance. The tiles used for the roofs of village houses are noticeable because many of them are black or nearly black like Staffordshire bricks. Fodder in the Miraj Chinchli country is generally stored in heaps in the fields. Each heap is covered with earth dug up in lumps and built up round and over the

heaps. Further south the same practice does not prevail to the same extent because the monsoon rain is heavy and fodder stored in this way would rot, In Belgaum and Dhárwár this method of storing *karbi* is practised to some extent. The *bhusa* is stored in small huts with steep conical roofs. They are built up with *jowári* stalks and sometimes plastered.

Soils in Sind.

The greater portion of the Sind plain has been deeply flooded and the soils are entirely alluvial. They vary in character from drift sands to stiff clays and are often strongly unpregnated with salt. The soil in parts of the province is so rich as to produce regularly two crops in the year without manure, but this is where the land is covered by the silt-laden flood water of the Indus or is irrigable by canal water. With the exception of Kohistán the Eastern Desert and the level tract which skirts the western hills where crops are grown with a scanty and precarious rainfall, the whole of Sind is practically dependent on the water of the Indus. The rainfall is so light that it is practically of very little value for cultivated crops. The river fed by the melting snow of the Himalayas, begins to rise in March. Later the flood is increased owing to the summer rainfall which swells the rivers of the Punjab which are tributary to the Indus and the maximum height is attained about the middle of August, after which the river begins to subside. The alluvial tracts on each side of the river which are submerged in the inundation season and large areas at a distance which are swept by the spill-water retain sufficient moisture when the water subsides to grow very fine late crops without the aid of artificial irrigation. But for the most part cultivation depends upon canals which take off from the river and distribute the fertilizing silt-laden water throughout the thirsty land. These canals are irregular in direction and follow the natural slopes of the country thus resembling natural water courses rather than canals. There is a difficulty in maintaining the canals owing to the vagaries of the river which may desert the mouth of the canal altogether, injure the mouth by erosion, or throw up a bank of silt in front of it. The canal water is loaded with silt, part is deposited in the canal and requires annual clearance. The silt deposited by canal water on arable fields is of immense value. It enriches the soil and enables the cultivator to dispense with manure for all ordinary crops. Manure is seldom used in Sind except for rice and wheat. The canal water flows through minor channels to cultivated fields or is lifted on to these by persian wheel. The silt deposited by the river water varies in character and consistence. It is provincially classified under various vernacular names.

General classification of Indian soils.

Dr. Leather classifies the soils of India into four main heads. The Indo-Gangetic alluvium, black cotton soil or *regar*, red soils lying on metamorphic soils in Madras, and laterite soils. The Indo-Gangetic alluvium is represented in the Bombay Presidency by the *gorádu* or *gorádu-besar* soils of Northern Gujarat. The soils of this class are characteristically deep, light

coloured, vary in consistence from drift sand to stiff clay loams, and have particles in a fine state of division excepting that they may contain nodular limestone or *kankar* which has been formed by the deposition of calcium carbonate. This *kankar*, if present at all, may be found in a bed at a considerable depth in these alluvium soils. Dr. Leather states, that in the soils he examined, the amount of phosphoric acid though not large is generally more than in other classes of Indian soils. The potash is sufficient, the amount of nitrogen and organic matter varies, but are generally low. Whilst those of iron, alumina and magnesia are somewhat higher than in English soils of similar class. The percentage of lime in the sandy soils is rather low, but a fair percentage is present in the loams and clays. The percentages of organic matter and combined water are low.

The proportions of important manurial ingredients in Indian alluvial soils.

I select the following from Dr. Leather's analysis as typical for each kind of soil found in Indus-Gangetic alluvium tracts :—

	Sandy soil.	Sandy loam.	Loam.	Clay or Clay loam.
Insoluble Silicate & Sand ...	91.72	86.06	82.96	72.64
Iron ($Fe_2 O_3$)	2.36	4.48	4.59	7.58
Alumina ($Al_2 O_3$)... ...	2.92	4.36	5.11	9.89
Manganese (M N. O) ...	Nil	.11	.11	.14
Lime (Ca O)	.35	1.03	1.78	1.01
Magnesia (MGO) ...	.78	1.48	1.53	1.64
Potash (K_2 O)	.33	.76	.66	.82
Soda (Na_2 O)	.08		.30	
Phosphoric acid ($P_2 O_5$) ...	.08	.09	.13	.07
Sulphuric acid (SO_3) ...	.04	.03	Nil	Nil
Carbonic acid (CO_2) ...	.27	.47	1.10	.28
Organic matter and water of combination	1.07	1.13	1.73	5.93
	100.	100.	100.	100.
Nitrogen	.027	.043	.045	.051

Analysis of black soils.

Regar or pure black cotton soil is well represented in the Bombay Presidency in Ahmedabad, Broach, Surat, parts of Dhárwár, Ahmednagar and Khándesh, but as already explained, the black soil so generally met with throughout the Deccan is mixed black and not true *regar*, I take the following analysis from Dr. Leather's report as typical of true *regar* soils :—

	Black Clay. Madura District No rain for a long time. Moisture 9' below surface.	Regar Clay. Anantapur dist. Pure black cotton soil.	Kurnool. Pure black cotton soil.
Insoluble Silicate & Sand ...	68.97	62.15	63.74
Iron (Fe_2O_3)	6.96	6.25	6.54
Alumina (Al_2O_3)	10.84	12.06	11.83
Manganese (MN. O) ...	.22	.15	.16
Lime (Ca O)	1.96	5.35	3.66
Magnesia (MG O)	1.90	2.50	2.78
Potash (K_2O)	.26	.21	.43
Soda (Na_2O)			.21
Phosphoric acid (P_2O_5) ...	.03	.06	.05
Sulphuric acid (SO_3) ...	Nil	.03	Nil
Carbonic acid (CO_2).. ...	.25	3.58	2.32
Organic matter and combined water	8.61	7.66	8.28
	100.	100.	100.
Nitrogen	.030	.043	.034

Proportions of important ingredients in black soils.

I gather from Dr. Leather's report that in pure black soil the percentages of insoluble silicates, iron and alumina are fairly constant within moderate limits. The amount of manganese is very constant. Lime varies in amount and also in the condition in which it exists. It occurs usually both on carbonate and as silicate. Magnesia is always present in high proportion. The alkalies (potash and soda) vary very considerably. The highest percentage found by Dr. Leather in any black soil was 2·44% and the lowest ·15%.

The percentage of phosphoric acid was low in all cases and black soils, and indeed all Indian soils are deficient in this ingredient. Dr. Leather explains that although the proportion of total phosphoric acid is generally or frequently low the *available* phosphoric acid is not usually deficient. The amount of nitrogen and probably also of organic matter (the latter was not separately estimated) was in all samples very small. Organic matter and nitrogen are commonly deficient in all Indian soils.

Red soils of Madras.

Dr. Leather's analysis of the red soils of Madras and of laterite soils indicate that these soils vary very considerably in character and compositions, and it is difficult to say what would be average analysis for these descriptions of soil. The principal lessons to be learned from the analysis are that the red soils of Madras are like other Indian soils deficient in phosphoric acid and nitrogen, and are not otherwise defective. The laterite soils are equally deficient in nitrogen and in some only traces of phosphoric acid were found.

SOIL FERTILITY IN RELATION TO PLANT LIFE.

Some of the conditions which affect soil fertility.

Fertility depends to a great extent upon those characters of the soil which have already been described. It is measured not only by a sufficiency of plant food existing in the soil for the time being but, also by the capacity of a soil to yield by proper management a continuous supply of those elements of nutrition which plants obtain from it. However fertile a soil may be, usually very little of its weight is at any time soluble. Continued fertility greatly depends upon the rate at which the mineral and nitrogenous substances in the soil are made more or less soluble by air, warmth, moisture, &c. The most important points in relation to fertility are that the soil must not only contain plant food in available condition, but this soluble portion must not be lost by too free drainage or be made inaccessible by any other fault. The absence in the soil of one of the elements of plant food is fatal to productiveness. There is no risk of this in any ordinary soil in respect of several of the elements of nutritive value, because ordinarily they are present in excess of the requirements of plants.

Constituents which are specially valuable in the soil or in manure.

Nitrogen, potash, phosphoric acid and lime are usually present in the soil in limited quantity and the addition to a soil as fertilizers of these when necessary, will secure in most cases a remarkable increase in productiveness. Elements that are usually considered of minor importance if lacking in a soil in a soluble form may be the direct cause of sterility. It is not usual to think of applying as manure any salt of iron, yet instances have occurred when such an application has had a marked influence on a soil's fertility. The explanation is that iron was either deficient in the soil or was present in an insoluble form. Iron is absolutely essential to plant life. It is required in the formation of chlorophyll grains, which give a green colour to leaves. Chlorophyll can only be formed in sun light and it is

believed that only in the chlorophyll-cells can plants assimilate a good deal of the food which they obtain from the soil and from the atmosphere.

The value of humus and clay.

The fertility of a soil does not alone depend upon all the elements of plant food being present in sufficient quantity and in assimilable condition. Nitrogen is largely supplied by humus, but plants have been grown experimentally in a soil containing no organic matter. All the same no one will question its immense value for it both stores and absorbs water, heats the soil by absorbing warmth, takes ammonia from the air, conserves from waste the manurial elements in the soil, and supplies nitrogen as well as carbon dioxide. Again, clay is not essential to a soil as a direct supplier of nutrition to plants. It must, however, be recognized as a soil-constituent which has an immense bearing on fertility.

The manner in which plant food is dissolved and then taken up by plants.

The ash or inorganic part of plants is taken up entirely through their roots, and in solution. Some ash constituents are soluble in pure water, some in carbonated water, and all to a greater or less extent in the acids which are found in humus and in those organic acids which are found in the roots of plants. Mr. Collins in his "Agricultural Chemistry for Indian Students" explains the dissolving action of these acids thus :—"If you try to clear the root of a plant from the adhering soil you will soon be convinced of the very intimate contact that exists between the root and soil. Considering this intimate contact it is obvious that diffusion of root sap takes place in the cell wall between the plant side and the soil side. Hence it is that it is the root sap that dissolves the soil. The root sap does not run out into the soil." The mineral food of plants and the nitrogenous food which are each derived from the soil bear a small ratio to the plant food derived from the atmosphere and from water. The carbon, hydrogen and oxygen obtained from the latter sources exist in ordinary plants often to the extent of 90 per cent. It is now pretty well understood in what forms the food of plants is taken up in solution. Nitrogen can only be taken up as nitric acid or nitrate. In this connection the nitrates of the alkalies, lime, soda, potash and of other bases (all being soluble) might easily find their way into the circulation of the plant in solution. The nitrogen is believed to be taken up chiefly as nitrate of lime. Phosphoric acid is probably taken up as phosphate of lime, sulphuric acid as sulphate of iron or lime, &c. ; silica probably as a silicate of one or other of the alkalies. These silicates are fairly soluble in soil water. Chlorine is probably assimilated as common salt. Ordinarily the ash elements necessary for plant nutrition exist in the soil to a great extent in much more insoluble combination than those which directly supply plant food. This is a precaution of nature to prevent waste. These more or less insoluble compounds coming in contact with the solvents existing in a fertile soil supply the needs of plants as quickly as is necessary.

Nitrogen and nitrification.

Nitrogen is the most important element because it is usually the scarcest. It exists in the soil in an organic form, as ammonia and as nitrites or nitrates.

As already stated it must be oxidized into nitric acid or nitrate before it is assimilable by plants. The process of nitrification plays an important function in the formation of nitric acid. Nitrification only proceeds in the presence of warmth, of moisture, and of oxygen. The presence of lime or any alkaline base is necessary to combine with the nitric acid as it is formed. The conversion of organic nitrogen or ammonia in the soil into nitric acid is brought about through the influence of the nitrifying organisms. These are present in all fertile soils. A sterilized soil can be inoculated with nitrifying organisms by mixing a little soil containing these bacteria with the soil that has been sterilized. Agricultural chemists during recent years have been able to throw considerable light on a practical means of supplying any ordinary soil with a large supply of combined nitrogen. Leguminous plants of the papilionaceous suborder have the power through bacteria which live in tubercles or excrescences on their roots of absorbing directly from the atmosphere free nitrogen which apparently is required as food by these bacteria. The free nitrogen is assimilated and converted into an organic form from which it can be changed by the nitrifying organisms into ammonia, nitrous oxide and finally nitric acid in which form it becomes directly available as plant-food. Nitrification chiefly takes place in the upper layer of soil within a few inches of the surface.

The growth of papilionaceous leguminous crops increases the stock of combined nitrogen in soils.

In the light of recent investigation as to the fixation of free nitrogen by leguminous plants it is probable that the question of rotation will in the future solve the difficulty of providing an artificial supply of nitrogen and make the cultivator independent to a certain extent. The value of leguminous crops will be more pronounced if their cultivation is associated with the principle of green manuring. The advanced cultivator in India knows full well the advantage of this practice although he has not the knowledge to reason out the cause. He has sufficient practical knowledge to be aware that *san* (a leguminous plant) ploughed in as manure is an uncommonly good preparation for sugar-cane, all cereals, and any other crop that is benefited by a fair supply of available nitrogen.

The value of leguminous crops in rotation.

The supply of nitrogen in the soil is replenished to a small extent by the combined nitrogen carried down by rain. The quantity obtained from this source is not, however, very great being only a very few pounds per acre annually. It has been proved that certain algæ growing on the surface of the soil have the power of fixing free nitrogen and it has been conjectured and almost proved that under the influence of silent electrical currents in the soil and in the plant, the free nitrogen of the soil air is converted into a nitrogenous compound which plants can assimilate

Soils obtain combined nitrogen from the atmosphere.

The value of nitrogen to a soil becomes the more apparent when we know that in its most soluble compounds it is very liable to be lost in drainage; heavy rain falling after a period favourable for active nitrification is certain

Nitrogenous salts are easily lost in drainage.

to cause loss and after a heavy rainfall more nitrogenous salts will be found in the subsoil than in the soil.

Potash and soda.

Potash and soda although they are presumed to be liberated from felspars and other minerals as carbonates are found in soils chiefly as silicates. These silicates are only to a slight extent soluble. Cultivation, the presence of decomposing organic matter, and the application of caustic lime tend to break up these combinations and liberate the potash and soda into their more soluble carbonate forms. Potash is generally fairly abundant in Indian soils.

Lime and magnesia.

Lime and magnesia occur in soils as carbonates which though insoluble in pure water are each soluble in ordinary soil water. In Indian soils these minerals also occur to a considerable extent as silicates. Lime probably is required in the formation of every cell. Its power in aiding nitrification has already been noticed, its utility in hastening the decay of humus and in ameliorating the sourness of some soils due to the presence of organic acids are each noteworthy. Magnesia is perhaps a more important plant food for some families of plants than for others, the analysis of wheat grain, for instance, shows that magnesia is indispensable in the construction of the outer integuments. Like potash and iron it is probably necessary in the formation of the chlorophyll grains, and possibly on occasion may replace lime to some extent in the tissues of plants.

Silica.

Silica when newly liberated from a silicate assumes an amorphous form in which condition it is soluble. It is necessary especially for cereals. It is a constituent of the straw and also of the outer membraneous coverings which protect the inner structure and the delicate germs of most cereal grains. The presence of common salt in a soil or its application as manure has some influence in making silica more soluble.

Iron and manganese.

Iron and manganese occur in soils in similar combinations. Manganese cannot take the place of iron in the formation of chlorophyll, but for other purposes in the economy of the plant these elements are believed to be more or less interchangeable.

Phosphoric acid.

Phosphoric acid next to nitrogen is perhaps the most important constituent necessary to fertility. It may exist in a soil as phosphates of lime, of magnesia, of iron, and of alumina; the two latter being less soluble than the two former. It can be artificially applied as manure in a still more soluble form, *viz.*, as monocalcic phosphate of lime. Fruitful soils contain about ·2 per cent. of P_2O_5.

THE SURVEY AND SETTLEMENT SYSTEM OF LAND CLASSIFICATION FOR FIXING ASSESSMENT.

The Survey Department have found it expedient to frame a system of classification for the purpose of ascertaining the relative values of different

kinds of soils whereby the classer although, he is allowed to a certain extent to exercise his judgment and experience, must at the same time conform to fixed rules which leave nothing to his uncontrolled will.

The conditions which determine the classes and orders of surveyed soils

According to this system all soils are ranged under nine classes and three orders. The depth of the soil decides the class, whilst the colour and consistence determine the order. The need of so many sub-divisions is especially necessary in the Deccan where owing to the broken character of the country the soils are very variable. The classer takes count of this and digs several test holes in each field the number of which is regulated by local orders. A tenth class has of late been added to the standard scale with the view to bring within the scope of classification lands of the poorest kind not fit for cultivation throughout but only in small patches here and there and the produce of which is only used as fodder. In other districts of the Presidency, especially in black soil tracts, there is not the same variation. There the classer generally only digs one hole in a moderately sized field and this test may sometimes show the character of soil found not only in that particular field but of a very large district.

The fertility of a soil in India is chiefly dependent upon its power of imbibing and retaining moisture. This quality is mainly affected by depth, colour and cohesiveness. The following tabulated statement explains itself :—

Class.	Relative value of class in annas.	Soils of		
		1st order.	*2nd order.*	*3rd order.*
		Uniform fine texture, colour varying from black to dark-brown.	Uniform coarser texture, lighter colour, usually red.	Gravelly or loose friable texture, colour light brown to grey.
		Depth in cubits.	Depth in cubits.	Depth in cubits.
1	16	$1\frac{3}{4}$	......	......
2	14	$1\frac{1}{2}$	$1\frac{3}{4}$	......
3	12	$1\frac{1}{4}$	$1\frac{1}{2}$	......
4	10	1	$1\frac{1}{4}$	......
5	8	$\frac{3}{4}$	1	......
6	6	$\frac{1}{2}$	$\frac{3}{4}$	1
7	$4\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
8	3	......	$\frac{1}{4}$	$\frac{1}{2}$
9	2	......	......	$\frac{1}{4}$

By the addition of the 10th class the values of the several classes from 7th downwards have been altered as follows :—

			as.	p.
Class	7	value	4	0
Class	8	,,	2	6
Class	9	,,	1	6
Class	10	,,	1	0

The orders, classes and values given in this table are only general and are modified in detail so as to suit local peculiarities and circumstances. $1\frac{3}{4}$ cubits (approximately 3 feet) is held to be the depth sufficient to ensure the maximum fertility in the case of the soils of the 1st or 2nd order. Soils of the 3rd order are rarely found of greater depth than one cubit. This depth is made the maximum.

Faults in soils are recorded in a classer's field-book by conventional marks.

There are soils which have a lower standard of fertility because they are affected by deteriorating influences, which when of sufficient importance determine such soils to be entered in a lower class than that indicated by depth. The faults of ordinary occurrence are recorded below and are distinguished by the following conventional marks being a convenient method of recording them in the classer's field-book.

- .·. Denotes a mixture of nodular pieces of limestone.
- V An inordinate admixture of sand.
- / Sloping surface.
- × Want of cohesion amongst the constituent particles of the soil.
- ∧ A peculiar mixture more or less impervious to water.
- ⁓⁓ Liable to be swept by running water.
- [ ] Excess of moisture from springs or otherwise.

Extrinsic circumstances affecting the value of a field such as distance from drinking water, accessibility or any uncommon circumstances are noted by the classer in his field-book, who as he effects the classification of a field enters an outline of its shape in his field-book and divides this hand sketch by intersecting lines into a number of equal compartments, sufficiently numerous to ensure a fair average valuation of the whole. This, however, is only necessary where there is evident variation in the soil.

Each plot is separately examined and classed, and the particulars entered in the appropriate compartment as shown in the following example :—

7	4 ∧ ∧ ⁓⁓	3 ⁓⁓	1	
$\frac{3}{4}$	$1\frac{3}{4}$.	$1\frac{3}{4}$.	$1\frac{3}{4}$.	$1\frac{3}{4}$
6	5	4 ∧	3	V/
1	1 ..	$1\frac{1}{2}$ ..	$1\frac{1}{2}$ ..	$1\frac{3}{4}$

The figures in the lower left hand corners of each square indicate the depth of the soil ; the number of dots under each of these figures, the order of soil. The conventional marks register the presence of faults. If a fault is very pronounced that may be recorded by entering the conventional mark twice or oftener. Each recorded fault degrades the soil one class. Thus the class to which the soil of any square belongs is determined by (1) the order to which it has been assigned ; (2) its depth, ; (3) the presence or absence of faults. It will be noticed that the right hand lower square of the example field is $1\frac{3}{4}$ cubits deep ; it belongs to the first order and that it has two faults. A glance at his notebook would enable the classer years afterwards to say that this particular portion of this field consisted of soil which was of dark colour of fine uniform texture ; that sand preponderated in it too great a degree, and that the surface sloped. The presence of these two faults lowered the soil to the third class or 12 anna standard. The figure 3 in the left hand upper corner shows the class. If the anna estimates of all the compartments are totalled and divided by the number of compartments the product will be the anna valuation of the field according to the adopted scale.

The foregoing diagram explained.

It is clear that the above method of determining the respective value of fields in the same village cannot apply to all the descriptions of soils which may be found there. The position of a field may enhance its value. Low-lying land may with advantage receive the drainage of fields lying higher and may for this reason be of higher agricultural value. If on account of its character a soil can be irrigated to advantage and there is positive evidence that sweet subsoil water exists at a reasonable depth, then a soil with these advantages should certainly bear a higher assessment than one which has not this superiority.

Circumstances which may enhance the value of particular soils.

The system of classification described above while it prescribes faults which operate to lower the value of a soil, took no count of the advantages which tend to raise that value. In the light of later experience, the Survey Officer has found it as necessary to prescribe a scale of increase for land having exceptionally good qualities, as to provide a reduction for lands having decided faults. In the Revenue Surveys which have been recently completed or which are now in progress, different scales of increases on account of different advantages have been prescribed under "the position class increase," "subsoil water classification," &c. There are lands possessing special qualities such as rice land, *bhátha* land, superior order or *uttam bágáit*, *etc.* of which the relative valuation cannot be accurately estimated by the ordinary dry crop scale rising to 16 annas such as the one referred to above. Special scales have been adopted for these special kinds of lands and arranged so as to meet local peculiarities in different parts of the Presidency.

Specially valuable lands are classed under scales different from the one described above.

Irrigation greatly increases the productive power of land and land which was irrigated by well water and classed as garden land had under the old system

Subsoil water rates.

of classification to bear a heavy water rate. This has been held to be a direct tax on capital invested by the owner in digging a well and it has accordingly been abandoned in the Revenue Survey; and in lieu thereof, an addition has been made in the classification of all lands adjudged to possess subsoil water advantages, irrespective of whether the advantage is utilized by the sinking of a well or not. Thus, in Gujarat where this measure has been largely applied the burden hitherto borne by the man who has had the enterprize to dig a well and, by means of water and manure convert ordinary dry crop land into rich garden soil will be considerably lessened. On the other hand the cultivator who has not had that enterprise hitherto will be stimulated to dig for water also, for where the presumption is that sweet water exists at a reasonable depth below the surface he will be taxed whether he digs a well or not if his land is suitable for irrigation.

The conditions which should influence the absolute amount of assessment to be levied.

The manner of distributing the assessment over the fields of a particular village has been described and the relative values of fields shown by an anna valuation. The next question is how Government fixes the absolute amount of assessment to be levied. There are several conditions which should influence this:—

(1) Climate particularly as regards rainfall and assured security from famine.

(2) Location. Whether near or remote from good markets.

(3) Means of transport provided by Government expenditure and Government provisions likely to improve the agricultural capabilities of the land and avert famine.

(4) The agricultural skill and consequent thrifty or unthrifty condition of the cultivators.

The above and other purely local conditions influence the Settlement Officers in dividing the villages of a *táluka* into various groups. Each group will have a different maximum rate.

The assessment on particular fields of a village is so arranged by "distance from village scale" that fields remote from the village bear a lighter assessment than similarly classed fields situate close to the village. This for obvious reasons is only fair.

THE FUNCTIONS OF THE ATMOSPHERE TOWARDS PLANT LIFE.

Plants need oxygen at all stages of growth.

The gases which constitute the atmosphere play an important part in plant life. How important that function is has not yet been fully determined by our best known agricultural chemists—a good deal is, however, known.

The seed of any plant is a medium whereby the species can be propagated. Each seed contains a store of concentrated nutritive material which

is intended by nature to support the tender seedling until it has provided itself with roots and leaves and becomes thereby independent. Moisture and oxygen are absolutely necessary to the process of germination and when this is known it becomes at once evident why seed should not be too deeply buried and why air should have free access to the soil. The growing points of all roots absorb free oxygen. This fact explains why stagnant water or anything else that prevents the free circulation of air in the soil causes an unhealthy condition of crops. The leaf buds, in the process of opening, require free oxygen and in the development of the inflorescence it is indispensable. The leaves of plants exercise two forms of respiration which are directly opposed to each other but go on at the same time. In the first form oxygen is inhaled and CO_2 exhaled. This action proceeds most energetically during the night. It is, however, also noticeable in daylight. In plants of a succulent nature oxygen is the largest constituent. The percentage weight of oxygen in the dry matter of any plant is only exceeded by carbon. Very little of the oxygen which goes to make up the structure of a plant is derived from free oxygen. It is believed that nearly all of it is derived from water which is absorbed through the roots from the soil.

The value of carbonic acid gas as plant food.

About one-half of the dry structure of a plant consists of carbon. This carbon is entirely derived from the carbonic acid gas of the atmosphere. In daylight the leaves of plants absorb carbon dioxide and give off oxygen. This respiration is a direct contrast to that already noticed. The decomposition of carbon dioxide takes place in the chlorophyll cells. In the presence of light aided by iron, potash and magnesia, the chlorophyll forms sugars or starch from the carbonic acid gas of the air and the water in the cells. Thus the leaves of plants in those cells which contain chlorophyll prepare an organic substance out of inorganic material.

Rain conveys more to a soil than mere water.

Plants receive no sustenance from the moisture of the atmosphere until it is condensed as rain or is deposited as dew. Rain carries more to the soil than mere water. In its passage through the atmosphere it takes up in solution those combinations of nitrogen which exist in the atmosphere. It has been known for years that every falling shower brings to the earth appreciable quantities of combined nitrogen. How does the atmosphere get its supply? This query is easily answered. When fuel is burnt, whether coal or wood or cow-dung, the most of the nitrogen goes off as free nitrogen but a little as ammonia in the smoke. The slow combustion or decay of many organic substances yield nitrogenous compounds which are dissipated to the atmosphere. The pungent and disagreeable smell which surrounds badly-kept stables points to the loss of ammonia from decomposing urine. The unhealthy odours met with in the insanitary neighbourhoods indicate gases, similarly generated, while the foul atmosphere surrounding slaughter houses, tanneries and many industrial manufacturing buildings account for the pre-

sence in the atmosphere of combined nitrogen in considerable quantity. Probably in the neighbourhood of towns and large manufacturing centres the rainfall conveys to the soil much more of manurial value than it does in the open agricultural districts. In England, the supply obtained in rural districts does not exceed 4 or 5 lbs. of nitrogen annually.

Nitric acid formed from free nitrogen and free oxygen during thunder-storms.

During thunder-storms the passage of electrical currents through the air causes free nitrogen to combine chemically with free oxygen—nitrous acid is formed—at the same time the electrical discharge concentrates oxygen into a form known as ozone which being more energetic in its action than ordinary oxygen, oxidizes the nitrous acid into nitric acid. The nitric acid coming in contact with free ammonia combines with it to form nitrate of ammonia and this compound is probably the form in which the combined nitrogen is carried to the soil dissolved in the rain-water. On account of the violent thunder-storms and electrical disturbances of minor importance which are common in the tropics probably a greater weight of combined nitrogen is conveyed annually from the atmosphere to the soil in India than in England, but there is no certainty that such is the case.

Ammonia absorbed from the atmosphere by certain soils.

It is a debatable point whether any other description of vegetation except the algæ already referred to have the power to absorb either combined nitrogen or free nitrogen through their leaves from the atmosphere, but it is certain that soils rich in organic matter and clay have the power to condense on their particles free ammonia from the atmosphere. The most feasible explanation of this power seems to be that the humus is a species of carbon and like it can absorb and concentrate gases, more particularly ammonia. The deodorizing power of good mould or indeed of any kind of earth is brought into requisition in the preparation of poudrette and in the earth closet system. The fox after he has made a raid on the poultry yard and has feasted buries the remains in the earth to be exhumed in a tasty condition when he is again hungry. The instinct of the dog directs him to bury his bone if it is to be preserved for future use ; whilst the cat the most cleanly of all animals buries its own excreta.

INFERTILE SOILS.

Causes of sterility.

Sterility may be due to various causes. A soil is seldom found absolutely barren if climatic conditions are favourable. The gradations between absolute sterility and high fertility are numerous. Unfruitfulness is accounted for in many ways. A soil may be so naturally poor that the most liberal management will not enable the farmer to raise from it remunerative crops. It may, moreover, have physical faults which, however, can at a cost more or less considerable be corrected. There may be substances present in the soil which are poisonous to vegetation. A poor soil may be deficient in one or other of the elements necessary to fertility, whilst a sterile soil may lack one or

more essential elements. Soluble salts which in moderate quantity are ordinarily beneficial may be present in such high percentage that they become the direct course of barrenness. Even 1 per cent. or less of certain soluble salts cause unhealthiness to ordinary cultivated crops. This explains why vegetation on *usar* or salt land tracts is sparce and unthrifty. Exhaustion may be caused by continuous cropping without manure. On the most fertile soil this practice must tend to lower the standard of fertility. And there is an obvious advantage in adding to an exhausted soil a manure specially rich in the element or elements in which the soil is deficient.

Means of renovating infertile fields.

Fallowing, rotation of crops and the addition of manure may each renovate a soil. By fallowing or rest, a soil may recuperate itself from its own resources. During the process of fallowing the mineral matter of the soil is actively attacked by the weathering agents so that new plant food is made available. And these natural agents act more vigorously and with greater effect if they are assisted mechanically by the free use of tillage implements. Thorough tillage will prevent the growth of weeds and will, moreover, allow air, moisture, &c., to exercise their full disintegrating power. The only objection is that in a soil containing nitrogen or organic matter capable of yielding nitrogen the tillage, which proper fallowing demands, may cause nitrification to proceed rapidly, and nitrates thus formed being extremely soluble may be washed out of the soil by a heavy fall of rain. The principle of bare fallowing demands that the soil be rested and at the same time be thoroughly cultivated. The practice is not unknown in the Presidency. In some *talukas* of the Broach Collectorate on black cotton soil it is systematically practised.

Fallowing.

The fields so treated are known as *rashil* fields. Fallowing is only practised on the more extensive holdings. The occupants can afford to allow a certain proportion of their lands to be fallowed every year. Excellent crops of cotton are got after a year's fallow without any manure. Where fallowing is systematically practised the holdings are thoroughly clean. In Broach the land is bare fallowed by ploughing four times and harrowing four times during the monsoon. Thereafter the harrow is used once a month up to the following June. Sometimes castors (Ricinus communis), *jowári* (Sorghum vulgare) or *tur* (Cajanus indicus) are drilled in single rows 12 feet apart in a *rashil* field. The intermediate space is fallowed in the manner described. The outturn from the single row repays to some extent the expenditure incurred whilst thorough tillage is not materially interfered with.

Waste land.

In the poor uplands of the Konkan and elsewhere in the Presidency when the soil becomes worn out by a succession of crops and there is no practical present means of making it recover its fertility, sometimes it is allowed to lie waste for years. When a certain number of years have elapsed it is again brought under cultivation. The land so treated although not fallowed in the true sense of the term recovers fertility. The practice is confined to districts where the rainfall is heavy. Ordinary fallowing would do

more harm than good there, because a heavy fall of rain would wash the loosened soil from the sloping ground to the lower levels. Whilst the land is lying waste the spontaneous growth of grass and of scrub jungle not only prevents erosion of existing soil, but conserves from waste any soluble matter dissolved from the soil's mineral store. Vegetation existing on the surface feeds on the soluble matter in the soil and prevents a serious loss which drainage would undoubtedly otherwise cause. Before these lands are again brought under tillage, the scrub growth is cut, laid evenly over the surface and burnt, and although the practice may be described as a wasteful one, the soil is undoubtedly enriched by the ashes, whilst on account of rest it has otherwise recovered sufficient fertility to produce a short rotation of crops consisting chiefly of the poorer hill millets.

The kinds of soils which are most benefited by bare fallowing.

In ordinary bare fallowing some soils are much more benefited than others. Clay or deep black soils are most suitable, because not only do they contain an immense locked up store of mineral wealth which may in part be liberated and need not be lost, because clay can hold the dissolved material against wash by drainage. A cultivator fallows his land chiefly to free it from deep-rooted weeds. When this is accomplished the wisest course would be to sow a green manure crop. The latter if ploughed into the soil would add to its fertility and would prevent loss by drainage, because the available plant food would be taken up by a growing crop. The practice of green manuring is called "green fallowing." Its object is to rest the land, and to keep it clean and to prevent waste. The green manure returns to the soil that which the crop has been able to collect in the soil or subsoil, and also a mass of organic matter which has been derived from the atmosphere.

Value of green manuring.

ROTATION OF CROPS.

A well arranged system of rotation usually maintains a fairly high standard of fertility for reasons given.

The fertility of a soil is ordinarily maintained at a higher standard if a well arranged system of rotation of crops is practised. The explanation is that, different families of plants require within certain limits plant food of different sorts or at least in different proportions. Some plants feed near the surface, others by means of their long tap roots go further afield for their sustenance. A deep-rooted crop may help the succeeding surface-feeding one, because roots which force their way into the subsoil collect a fair proportion of their plant food there, and the fallen leaves, the decaying roots and other residue add fertility to the upper layer of soil and provide plant food for a succeeding surface-feeding crop. The system of growing mixed crops so common in India is undoubtedly a successful and profitable method which probably has done more to uphold the fertility of Indian soils than any other practice. At any rate there is a very good reason why the Indian *rayat* finds it profitable to grow pulses, oil-seeds, &c. subordinate to his *jowári*, *bájri* or other cereals. Owing to variableness of season and general fickleness of

climate the Indian cultivator is at seed time, most uncertain as to harvest prospects. His experience or the experience of his forefathers proves that the risk of total failure in an unfavourable year is minimised by growing a mixed crop; besides the available labour is more evenly distributed throughout the year. If the cereal fails the pulse may succeed or *vice versa*, and to use a common saying, "All the eggs are not carried in one basket." Pulses auxiliary to cereals, undoubtedly, exercise another beneficial influence. In the light of recent investigation we now know that although leguminous plants actually remove more nitrogen from the soil than cereals do, yet they also leave the soil richer in combined nitrogen than before they were grown. I have already described how they indirectly fix in organic form the free nitrogen of the air in the soil, and keeping this fact in view we begin to understand how the *rayat* in India on the best class of soil has been able to grow mixed crops year after year on the same field without the help of manure. It may be conjectured, although it cannot easily be proved, that by growing pulses and cereals mixed, the former during their growth are preparing available nitrogen, which is assimilated by the latter. In India it is of extreme importance that a full supply of nitrogen should be available, because it is the element which in Indian soils is most deficient. It may be argued that although pulses are known now to be fixers of nitrogen, it has not been proved that a cereal crop grown with them can assimilate the nitrogen as it is being fixed. If we accept the theory that it does, we must also assume that the nitrogen first fixed in an organic form is nitrified into a nitrate or nitric acid. The presumption is that, this actually takes place. In support of this view I will notice the practical experience of farmers in respect of growing mixed rye grass and clover in England. The former belongs like Indian cereals to the grass family of plants; the latter is a leguminous plant. The yield per acre of the mixed crop ordinarily exceeds that of clover grown alone, sometimes it does not; but in either case it is the experience of every practical farmer that a much better crop of wheat is got after clover alone than after the rye grass mixture. The successful practice of growing mixed crops in India points to the fact that the practical experience of the uneducated Indian *rayat* has determined centuries since a means of providing an inexhaustible supply of nitrogen for the soil, whilst enlightened European agricultural chemists have only recently begun to see the way. It is a common saying in England, "Wheat after beans or clover;" the Indian *rayat* has similar though not identical experience; he knows that a leguminous green manure crop is a very good preparation for sugar-cane, (Saccharum officinarum), that gram (Cicer arietinum) or ground-nut (Arachis hypogia) are each uncommonly good rotation crops with cereals, that *tur* (Cajanus indicus) a deep-rooted pulse has a decidedly ameliorating effect upon the soil fertility and that a second crop of *rál* (Dolichos lablab) taken on rice (Oryza sativa) land in seasons when the land holds sufficient moisture after the cereal is harvested, enriches the soil for the rice crop of the following year.

The value of mixed crops.

The special value of pulse crops in rotation.

Rotation beneficial in other ways.

Rotation is beneficial in other ways than those already noticed. The most casual observer must observe that weeds grow much more freely in some crops than in others. Cotton or any crop that does not completely shade the ground encourages weeds. Thorough hoeing will suppress weeds in any crop, but sometimes with heavy rain the fields cannot be weeded properly. It is noticeable that a crop of gram or of ground-nut or of those pulses which have a trailing habit of growth will kill out surface weeds by smothering them. A good crop of either of the plants named should form a matted mass over the surface of the soil. A rotation in which gram or ground-nut takes a prominent place will to some extent ensure that the land under ordinary tillage will remain tolerably clean. The successful cultivation of some crops demands that the soil be kept absolutely clean. One need not look for a good crop of potatoes (Solanum tuberosum) or onions (Allium cepa) or of turmeric (Curcuma longa) or ginger (Zingiber officinale), of chillies (Capsicum frutescens) or sugar-cane unless the soil is well stocked with manure and is absolutely clean. The tillage of these and other garden crops is only undertaken by well-to-do cultivators and indicates a due appreciation of systematic rotation and an advanced system of husbandry.

Disease and insect attacks are induced by continued cultivation of the same crop on the same land.

All cultivated plants are apt to degenerate and become subject to disease if grown without intermission on the same land. Moreover, a plant which on this account becomes of low vitality is much more subject to insect attack than one which is robust and healthy. Some crops when grown year after year on the same field degenerate more quickly than others. Potatoes if grown continuously on the same field will in a very few years become diseased; any crop subject to fungoid disease should not be grown often on the same land. The spores or disease germs harbour in the soil for a season often in an inactive state but ready to again attack, under favourable conditions, the host, when it is planted. If the germs cannot find a proper host they die. The period necessary to kill fungoid spores or germs may vary with different diseases. The danger of infection is lessened if the host plant is grown at intervals of at least three or four years. Every crop is more or less the subject of insect attack. The danger is increased if the same crop occupies the same fields during successive years. The life history of every crop pest proves that the insect assumes different forms at different stages. A moth may lay its eggs which in time hatch. The caterpillars produced from them feed upon the tissues of the plant. They thrive and when full grown surround themselves with a chrysalis case. The pupa thus formed may hibernate in the soil or elsewhere for a period, but sooner or later a moth will emerge capable of propagating the pest in an incalculable degree, and the risk of loss is much increased if a crop is at hand, suitable to feed the caterpillars so soon as they are hatched.

In the Bombay Presidency irrigated garden crops are systematically rotated. Less attention is paid to the rotation of purely dry crops. The reason is that everywhere on dry crop land the practice of mixed cropping prevails and the practice obviates to some extent the necessity of other rotation. Again climate interferes somewhat. The rainfall limits the cultivation of rice and some other crops to well defined areas. Again the character of the soil regulates the particular kind of crop which is the staple in districts where the rainfall does not exceed 30 or 40 inches.

Rotation is practised to a greater extent among irrigated crops than among dry crops.

In tracts of very heavy rainfall rice occupies the bunded fields of the lowlands and is also grown to considerable extent on the artificially terraced slopes of the uplands. Where rice is so grown, it occupies the same land year after year. Where the opportunity offers, however, *vàl* or some other pulse crop is taken as a second crop after the cereal; the land thus being twice cropped in one year. The practice amounts to a rotation and by no means a bad rotation.

Rice lands.

On the poorer *varkas* lands of the uplands when the rainfall is heavy, the following sequence of crops is ordinarily taken :—

Varkas lands.

1st.—*Nágli* (Eleusine coracana.)
2nd.—*Vari* (Panicum miliaceum.)
3rd.—*Harik* (Paspalum scrobiculatum.)
4th.—*Khurásni* or Niger seed, (Guizotia abyssinea.)

If the land is good *varkas* land then two crops of *nágli* may follow each other during the first two years. At the end of the rotation the soil is exhausted, and is allowed to lie waste for 5 or 10 years to recover fertility.

In the black soils of Khándesh, Broach, Surat and Dhárwár, cotton is the staple crop. It requires a moderate rainfall. In each of the districts named, it is ordinarily rotated with *jowári*, but there may be local or climatic circumstances which cause occasional variation in the ordinary rotation. In all cotton districts if cotton and *jowári* are continuously rotated *kunda* and other deep-rooted weeds get established, because the land cannot be properly ploughed except at great cost after the crops are harvested. It becomes advisable if not necessary to periodically clean the land. If as is the case in Khándesh a *rabi* crop of wheat (Triticum sativum) or gram is occasionally grown, there is fair opportunity between June and October of cleaning the land; again if a crop of sesamum (Sesamum indicum) is taken as a *kharif* crop, it can be reaped early when there still remains a good deal of moisture in the soil which enables the owner to plough the land expeditiously; and if the land is once stirred before it sets hard it can be repeatedly ploughed during the following cold and hot seasons and made thoroughly clean. In Dhárwár and Surat the ordinary cotton-*jowári* rotation is lengthened occasionally by taking a crop of wheat. In

Rotations in black soil.

Broach the rainfall is heavier and the rotation practised is somewhat different. If the rainfall is more than ordinarily heavy the field intended for cotton (Gossypium) may be left unsown during the monsoon and either *láng* (Lathyrus sativus) or wheat (Triticum sativum) be sown as cold weather crops. The *láng* prefers a low-lying damp field. Wheat also needs moisture but not in any excessive degree. In many cotton fields in Broach rice (Oryza sativa) is drilled with the cotton presumably as a precaution in case the rainfall proves too heavy for the cotton. The *jowári* (Sorghum vulgare) of Broach is a *rabi* crop whilst that of Surat, Dhárwár and Khándesh is a rain or *kharif* crop. In a *jowári* rain crop there is invariably a subordinate mixture of pulses, oil-seeds and fibre plants. The *rabi jowári* is grown alone.

In cotton districts we have therefore the following occasional departures from the ordinary cotton-*jowári* rotation :—

IN KHANDESH.

1st year—Cotton.

2nd year—*Jowári*, *udid* (Phaseolus radiatus.) and *ambádi* (Hibiscus cannabinus.)

3rd year—*Til* (Sesamum indicum) or gram (Cicer arietinum) or wheat.

IN SURAT AND DHARWAR.

1st year—Cotton.

2nd year—*Jowári* with subordinate mixture.

3rd year—Wheat or *til* or a mixed crop of *tur* (Cajanus indicus) and *til*.

IN BROACH.

1st year—Bare fallow or *rashil*.

2nd year—Cotton or mixed cotton and rice.

3rd year—*Jowári rabi*.

4th year—*Láng* or wheat.

In the deep black land of the Tapti Valley, wheat is the principal crop and is grown often for several years in succession. All the crops grown are *rabi* crops and those occasionally rotated with wheat are gram and linseed (Linum usitatissimum). In the Deccan on the deeper black soils *jowári* is the principal cereal. It gives place to *bájri* (Pennisetum typhoideum) when the soil is light and thin. Both the *jowári* and *bájri* have usually subordinate pulse and fibre crops, and are grown in rotation with either wheat, gram or *khurásni* (Guizotia abyssinea). The most common pulses of the Deccan are *kulthi* (Dolichos biflorus) and *udid* (Phaseolus radiatus), whilst *ambádi* (Hibiscus cannabinus) is the common fibre plant. At Ahmednagar

jowári with subordinate rows of safflower (Carthamus tinctorius), wheat with safflower and gram are rotated, and the chief harvest in that Collectorate on black soil is *rabi.* Rain crops of *bájri*, &c., are grown on the lighter soils.

Rotations in the gorádu and besar soils of Gujarat.

Throughout the *gorádu* lands of Gujarat the dry crops grown are of greater variety than any other part of the Presidency. On *besar* soil *jowári* occupies the important position, that *bájri* does on the lighter *gorádu* fields. Each is the principal crop of its year, and subordinate to either may be found *tur*, *gurár* (Cyamopsis psoralloides), math (Phaseolus aconitefolius), *mug* (Phaseolus mungo), *chola* (Dolichos Catiang), *rál* (Dolichos Lablab), cotton, *til* (Sesamum indicum), castors (Ricinus communis), *sheria ambádi* (Hibiscus cannabinus)—not all ordinarily in one field ; the subordinate mixture is made up according to the inclination of the cultivator and usually consists of three or four kinds of pulses, with a sprinkling of oil-seeds and fibre plants. *Kodra* (Paspalum scrobiculatum) is in Gujarat recognised as an exhaustive crop in *gorádu* soil. It is never grown alone in the same field during two consecutive years ; *tur* mixed with it is believed to counteract its impoverishing power and *kodra*, is commonly grown mixed with *tur* and *til*. This mixed crop is taken year and year about with *jowári* and its subordinate mixture, or with *bájri* with its subordinate mixture. Occasionally a crop of *nágli* (Eleusine coracana) raised from transplanted seedlings may be substituted for one or other of the mixed crops.

On black soil in Gujarat occasionally the following *rabi* mixed crop is grown :—*Tur*, castors and *til*. The variety of cotton intersown in *bájri* or *jowári* fields in the *gorádu* soils of Gujarat is a perennial variety called *Rozi*. The *bájri*, *jowári*, *tur*, *kodra* and the cotton are drilled in separate rows. The castors, all pulses of a trailing habit, also *til* and fibre plants are either sparingly broadcasted or the seed sown is mixed before sowing and then the subordinate mixture occupies the same rows as the principal crop. *Tur* is generally absent or sparingly sown when there is a fair proportion of *math*, *mug*, *chola*, *udid* and *rál*, because if *tur* stands thick on the ground it shades it and has a tendency to suppress other plants. Each crop is harvested as it ripens. *Til* and *ambádi* generally come first, then the cereals. The pulses which are deeper rooted and can seek further for moisture ripen later, whilst *tur* comes last of all. Its long tap roots extending far into the subsoil enable it to withstand drought for months. It branches out and completely shades the ground after all the other crops are harvested, and the mass of leaves which fall as the crop ripens places *tur* in the forefront as a crop likely to maintain the fertility of the surface soil.

The ordinary rotations on light *gorádu* and *besar-gorádu* soils may be thus tabulated :—

	Light Gorádu.	*Besar-Gorádu.*
1st year	—*Bajri* (Pennisetum Typhoideum) with subordinate mixture.	*Jowári* (Sorghum vulgare) with subordinate mixture.
2nd ,,	—*Kodra* (Paspalum scrobiculatum), *tur* (Cajanus indicus), *til* (Sesamum indicum).	*Kodra*, *tur*, *til*, tobacco (Nicotiana rustica.)
3rd ,,	—*Nágli* (Eleusine coracana) (occasionally taken.)	*Nágli* (occasionally taken.)

Panch Mahals.

In the Panch Mahals, maize (Zea mays) is the staple crop. It is grown often every year on the same land, but usually a second crop of gram or wheat is taken.

Rotations in garden lands.

In the cultivation of garden crops the principles of rotation are more strictly adhered to than in ordinary dry crop cultivation. Deep soils of a friable character are best suited for irrigation. Where these exist, and when well or canal irrigation is available garden cultivation is started by well-to-do cultivators. The garden lands near to Surat are very fertile and the methods of cultivation can hardly be excelled. The crops grown follow each other in rapid succession ; ordinarily the land is double cropped each year. The more common crops are sugar-cane (Saccharum officinarum), ginger (Zingiber officinale), turmeric (Curcuma longa), onions (Allium cepa), garlic (Allium sativum), potatoes (Solarum tuberosum), cabbages (Brassica oleracea), sweet potato (Ipomæa batatas), ground-nut (Arachis hypogea) and *surans* (Amorphophallus campanulatus). The *suran* or elephant foot takes 4 years to gain its full size. It is dug up and replanted on fresh ground every year. Neither the *suran* nor any other crop occupies the same plot in two successive years, and it is by no means uncommon to find each of the crops mentioned occupying part of a single garden in the same year.

Surat district.

Thána district.

In some of the magnificently cultivated gardens which occupy a belt of sand land fringing the seacoast at Máhim in the Thána Collectorate there is never any departure from a regular rotation. The invariable order of crops is :—

1st.—Betel-vine (Piper betel).
2nd.—Ginger (Zingiber officinale).
3rd.—Sugar-cane (Saccharum officinarum).
4th.—Plantains (Musa sapientum).

Poona district.

In the Poona district garden cultivation is extensively practised in the Khed and Junnar *talukas*. The irrigated crops raised are grown in the cold

season only. The soil is medium black with a substratum of *murum* and well water is found at a moderate depth. *Bájri* (Pennisetum typhoideum) is sown as early in the rains as is possible, and as soon as it can possibly be harvested it is removed from the field, and tillage for the irrigated crop begins. The garden crops grown are potatoes (Solanum tuberosum), onions (Allium cepa), chillies, (Capsicum frutesceus), and ground-nut (Arachis hypogea). The potatoes are ordinarily taken too often on the same land, but the best cultivators have found it expedient to adopt a system of rotation of which the following is more or less a modification.

1st year—*Bájri* followed by potatoes.

2nd ,, —Ground-nut irrigated once or twice in cold season.

3rd ,, —*Bájri* followed by onions as a cold weather irrigated crop.

4th ,, —Chillies.

Ordinarily, however, *bájri* followed by potatoes is taken for two or three consecutive years.

AGRICULTURAL CAPABILITIES OF SOILS.

Climate affected by various conditions.

This is their power to grow healthy crops and indirectly produce healthy vigorous animals. Probably climate influences this more than any other condition. The effect of light, heat and moisture on vegetation is expressed by the one word " climate." And as these conditions are all due to the sun's rays vegetation is most active as the equator is approached. The climate of a country or a district depends upon other conditions than its latitude. In this connection we have to consider altitude, proximity to the sea, to lakes, marshes, rivers or to an arid waste, the character of the soil itself, natural shelter, nearness to forests and mountains. We find particular crops or plants thriving best under special conditions of soil and climate. In fact, it may be asserted with confidence that every field has inherent qualities which fit it to grow best a distinctive crop.

Latitude and altitude.

Generally the value of land depends upon its physical character coupled with the average rainfall and the average warmth. Good land may be situated at a latitude or altitude where the degree of cold prevents any crop ripening. Nothing grows at the poles nor on the higher peaks of the Himalayas and other high mountains. Cereals or any grain will only ripen a certain way up the slopes of high mountains. In cold countries wheat will only ripen at elevations slightly above sea level.

The conditions which cause assured rainfall in some parts of India and drought in other parts.

In Sind and other parts of India there are immense tracts which are worthless for cultivation, because there is little or no rain and no present means of irrigating; yet the land is good. Certain tracts are subject to periodic famine, whilst others in the Bombay Presidency

situate along a considerable stretch of coast line enjoy a rainfall so heavy and so assured that rice is the staple crop. The heavy rainfall is due to a chain of hills which run parallel to the coast. The monsoon winds laden with moisture strike the higher ridges, get cooled, and the condensed moisture falls as heavy rain. The heaviest fall is on the gháts, but there is always a steady downpour on the belt of land lying between the hills and the sea. More inland the rainfall rapidly diminishes, 100 miles inland the average rainfall is 1/5 to 1/8 of that on the gháts. A large extent of forest would have a similar effect on rainfall to a range of hills. Nearness to the sea gives usually an assured rainfall and an equable climate.

Effect on vegetation by proximity to lakes, marshes and the sea.

Low-lying land in proximity to lakes and marshes has often a chilling and unhealthy effect upon crops and animals. Cultivated plants that are naturally seaside ones will not usually properly mature at a distance from it. The cocoanut palm will not ripen its fruit at a greater distance inland than 150 miles. The cultivated forms of plants found wild on the coast retain sufficient of their natural character to require special treatment under cultivation. Thus beet-root (Beta maritima) or asparagus (Asparagus officinalis) (both seaside plants in the wild form) are under cultivation considerably benefited by the use of common salt as manure.

Average temperature effect on vegetation.

The average temperature affects the agricultural capabilities of soils. Wheat takes eight months to mature in England, about 4½ months in India, and on the great wheat plains of America often only 100 days elapse between seed time and harvest. It is observable that when a crop is forced by heat to ripen quickly the outturn per acre is less satisfactory. The average yield of wheat per acre is approximately

In England	33	bushels.
In India	8 to 10	„
In United States of America ...	10 to 13	„

It may, however, be noticed that a well nourished crop in a hot country produces grain of very fine quality. Indian and American wheats may weigh up to 66-67 lbs. per bushel; English seldom exceeds 62-63 lbs. The fodder value of Indian wheat straw is also, I believe, superior to English. I judge of this by the fact that wheat straw is the only fodder supplied to work-cattle on the great wheat plains where wheat alternates with indigo (Indigofera tinctoria). The work teams are constantly employed the year round—cattle doing such work fed on English wheat straw would literally starve. The soils in hot countries are further enhanced in value, because they can produce two crops in one season and can produce a

much greater variety of crops than soils in cold countries, but the variety of crops depends somewhat upon the character of the soil.

The character of the soil and of the climate determine the kinds of crops which can be most successfully grown, the quality of fruit and of various economic products being greatly affected by climate, &c.

A loam can grow any kind of crop. A clay is only adapted or certain kinds, whilst a limestone soil has its own natural vegetation; but apart from all this there are conditions affecting the producing power of a soil which the most expert enquiry cannot detect or gauge. Perhaps, no kind of vegetation is influenced by soil and climate to such an extent as fruit trees especially as regards the quality and flavour of the fruit they produce. The Nagpore *santras* (oranges) are believed in India to be the finest flavoured in the world. They certainly surpass in piquancy of flavour *santras* grown elsewhere in India, and the only explanation that can be vouchsafed is that the elevation, the soil and the mean temperature at Nagpore favour the production of fruit of the finest quality. The Alphonso, Piree and Mazagaon mangoes as grown at Bombay and near the coast have a decidedly superior flavour to the same varieties as produced at Poona and at other districts of the Deccan having a dry bracing atmosphere. Apples are grown at Kumaon and other parts of the Himalayas with a flavour and texture much finer than those grown in less favorable situations. The fragrance and strength of tea depend to some extent upon care in manufacture, but there are districts where the ordinary crop is appreciated at a much higher value than that of other districts. Even the gardens of one district differ considerably in respect of the reputations in the market of their respective crops. Undoubtedly, soil and climate exercise a considerable influence on the quality of tea. And so with many other economic products. Havana tobacco is grown in Gujarat, but it is doubtful whether it produces any better quality of leaf than the indigenous sort which certainly cannot be made into a cigar, equal in quality to an imported Havana one. Something in the character of the soil and climate is at fault. It is not the manner of curing, for the cultivators have had the benefit of expert advice without benefit in the slightest extent. I know a small stretch of country which comprises but a small corner of the vast Dominion of Canada, where many kinds of fruit come to mature perfection. The district referred to extends from Niagara to Hamilton in Ontario. It produces apples pre-eminently good, whilst peaches and grapes ripened in the open air can hardly be surpassed in quality. No doubt the soil of the district suits these fruits, but the equable humidity of the climate and the unchangeableness of the summer weather induced by proximity to an immense sheet of fresh water are the conditions which probably regulate the uniformly prime quality of the fruit grown.

The health and development of farm animals are greatly affected by surrounding natural conditions, and the same natural law applies equally to crops.

Indirectly as well as directly the character of the soil and its climate have a great influence upon the health and growth of domesticated animals. We find particular breeds peculiar to certain districts and their characteristics bear the stamp of the respective districts where they are bred. Cattle, horses or sheep bred in a district having good natural advantages, if moved to a district inferior in respect of these advantages, must produce degenerate offspring if left to grow and live under natural conditions. Any attempt to improve the size and quality of the indigenous domesticated animals of any district will fail unless food of better quality and in more abundance, and other necessaries be likewise provided. The same natural law can be applied with equal force to the cultivation of crops as to the breeding and rearing of animals. Exotics, whether animal or vegetable, must be introduced with caution and with some degree of misgiving. It does not follow that because a particular kind of barley produced a fine malting sample when grown in England or in the cooler parts of Northern India, it is bound to do the same in the Deccan, nor is it at all certain that because a fine long stapled silky cotton is grown successfully in Broach the seed of this variety will give equally good results in Khándesh where a short stapled inferior variety is commonly grown. There is ample evidence to prove that the reverse is the case. Acclimatization may aid in producing a successful issue, but even with this help it will be found that the agricultural capabilities of soils depend upon conditions which are arbitrarily indigenous and often purely local.

DRAINAGE.

In India artificial drainage is not so necessary as in some countries.

Stagnant water in a soil materially lowers its agricultural value. Fertility greatly depends upon the relation of the soil to the water which falls upon it as rain. In India it is not necessary to devote the same attention to artificial drainage as in some countries. The reason is that seasons of heavy rainfall and of prolonged drought generally alternate. A heavy downpour of rain may swamp a field temporarily and low-lying spots may suffer accordingly, but if the soil is deep and the water gradually soaks into it the occupier is glad to husband this moisture even to the extent of wetness, because it may, during the fair season, prove of considerable value. There are, however, situations where artificial drainage is undoubtedly useful. Many fields adjoining irrigation canals in irrigated districts become owing to their low-lying position surcharged with water, and will continue so as long as there is leakage from the canal or excessive drainage from the lands actually irrigated. Land often lies waste from these causes and yet it could be made easily culturable by providing an artificial outlet for the accumulated water. It may be taken as proved that all systems of irrigation must be associated with a natural or artificial drainage system to permit the superfluous water of an irrigated

Successful irrigation must be associated with natural or artificial drainage.

district to escape ; otherwise unsatisfactory, often unhealthy, conditions will assuredly be caused.

The necessity for drainage can easily be detected. The results which follow drainage discussed.

It is easy to detect indications of want of drainage. The soil may be so water-logged that water stands so near the surface that it is easily discernible to the eye. An excess of underground water will in time produce vegetation which is more or less aquatic in character. In water-logged grass lands sedges and rushes will replace the true grasses, and the latter will show a want of vigour indicated by a dwarfed growth and an unthrifty colour. Land previously wet to excess can be completely changed in character by thorough artificial drainage. Wet lands get soured and poisoned by the presence of organic acids. If the land is drained, the atmosphere is free to enter the soil. Aeration follows and these organic acids are oxidized so that they become either innocuous or actually beneficial in affording useful plant foods. By drainage the humus of the soil is brought under the influence of oxidation and therefore decays. The temperature of the soil is raised because heat previously absorbed in evaporating the excess of water goes to warm the soil particles. The climate is improved and becomes more healthful because dampness induces malarial diseases. The natural herbage becomes finer and more nutritious and the mechanical condition of the soil is changed. It becomes more friable and much more easily stirred by tillage implements. If a pit be dug in the earth two feet deep and if water drains into it at any season of the year in India, excepting during the rains, we may take this as proof positive that the soil requires drainage. There is a water level in every soil. If we dig down far enough we find well water. If by digging water is found near to the surface, the land must necessarily be water-logged. If the soil is gravelly or sandy and therefore too open, the subsoil water level is probably far below the surface and such land is naturally drained—probably too well drained. If on the other hand the soil is retentive and deep, or if there is a still more retentive substratum the water bearing level is probably so near the surface that the soil is kept excessively wet. The subsoil water level in any soil may be lowered by artificial drainage. The principle of underground drainage is that, any excess of water in a soil can be removed by artificial underground channels.

Water level

Soils which specially need drainage.

The soils which urgently call for drainage are :—

1st.—Dense sticky clays which on account of the fine state of division of soil particles obstruct the free percolation of water.

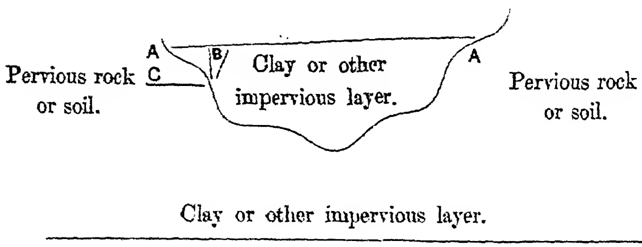
2nd.—Soil wet from position, *i.e.*, low-lying land receiving the drainage and flood-water from higher levels and, in particular, lands lying lower than an artificial irrigation channel or not far distant from it.

3rd.—Land kept wet by water breaking out as springs at particular

Springs.

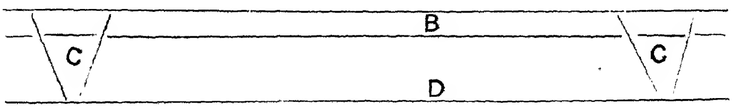
It may be taken that water which flows from springs has fallen as rain on distant higher level; that it has filtered through porous beds to a lower water-bearing stratum; that it has accumulated there; and that a further fall of rain tends to raise this water level so that there will be an increased flow of spring water from the outlet. Spring water can be tapped at the point of outlet and carried away by a drain.

The following diagram will show how subsoil water finds an outlet as spring water.



The spring water will escape at the points A A; if, however, the drain B is cut, the water level in the pervious rock or soil may be kept permanently at C or lower if the drain B provides a sufficient outlet at all seasons for the spring water which would escape at A A if there was no drain.

It has been already stated that in a water-logged soil the water level is very near the surface. In the following diagram the surface of an undrained field is represented by the line A, the water level by the line B, and a cross-section of two drains by C C.



The manner in which excessive water is removed from soils by underground drains.

When these drains are cut the water level will be reduced to D, if there is a proper outfall for the water and provided that the drains are near enough to each other to dry the intervening space. When the water level has been reduced to D the soil above is kept moist by capillarity and each succeeding

shower further moistens it and tends to raise the water level. In a period of heavy rainfall the rain may sink through the soil so fast that the outlet provided by the drains cannot carry away the water fast enough. Consequently the soil gets wet, perhaps to excess, but when the rain ceases the drains gradually carry away any surplus of water. During a period of drought the water level may sink lower than D because the supply of water in the soil is expended in evaporation and in supplying the needs of vegetation. But the next fall of rain will soak through the soil and raise the water level until the water escapes by the drains. The deeper the drains the sooner the water will escape. Consequently deep drains discharge water sooner after rain than shallow ones. Water enters a drain from below not from above.

The arrangement of drains in a field.

The arrangement of drains in a field will be regulated by the contour or slope or slopes of the field. If the field is tolerably level it does not matter much where the drainage begins. If, however, the field slopes in any one direction the drainage should commence at the lowest part of the slope so that the main drain cut there may afford an outlet for the water from the upper parts. If there are planes of inclination in more than one direction, each slope should have a system of drainage for itself beginning at the lowest point of each slope.

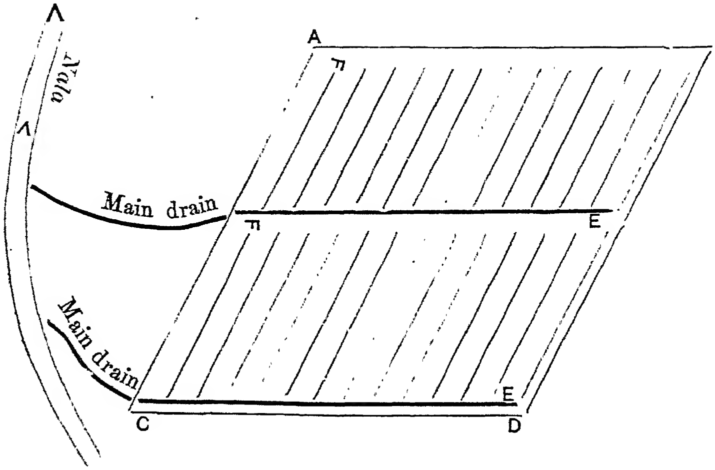
The drainage of field described.

In draining a field the first consideration is where to get an outlet. Any *nála* or stream will do if it is somewhat lower than the level of the land to be drained. By the use of a spirit level it can easily be determined whether there is a definite fall towards the outlet from the portion which require drainage of the field. Each drain must have a definite minimum fall from its upper towards its lower end. When the surface is level or nearly so, the desired fall may be obtained by deepening the drain gradually as the outlet is approached. If the field has a decided slope in one direction, one main drain cut along the line of lowest level may convey all the water from the field to the selected outlet; but a field may have a number of slopes. Then one main drain cannot properly carry away all the water. Each slope must have its own main drain and its own system of minor drains. Minor drains should run as near as possible straight up a slope. The main drain is cut first and each minor drain is cut from the lower end towards its upper end. This permits the water to escape as it filters into the drains. The fall should not be less than 1½ inches in a chain (22 yards) and not more than 8 inches. If less than the minimum sediment is deposited and obstructs the underground channel. If more than the maximum the water runs so quickly that if pipes are used they will probably be dislodged and put out of continuous position. A properly cut drain should not be more than 14 inches wide at the top and 4 or 5 inches at the

bottom. Clay tile-pipes are usually used to provide underground channels for water. $1\frac{1}{2}''$ to $2\frac{1}{2}''$ diameter pipes are usually large enough for minor drains, and 4" to 7" diameter pipes for main drains. The drain when dug is finished off in the form of a groove in the bottom, so that a bed is formed in which the round pipe is laid securely so that it is not easily displaced from position. Other materials, besides tile-pipes, will provide a free underground passage for water. Stones do very well if broken into angular pieces to fill about one foot of the bottom of a drain. A layer of turf or brushwood or coarse litter should be laid above stones before the excavated earth is returned to the drain. The object of having tiles or stones in a drain is to provide a channel through which water will flow after the drain is refilled with the soil excavated in forming it. Land can be equally well drained by open ditches ; but if a field is excessively wet this method cannot be recommended, because the ditches must necessarily be close together and tillage operations are therefore interfered with. Moreover, open ditches get overgrown with vegetation, and for this and other obvious reasons require to be periodically cleaned out at considerable cost. They are objectionable also because they entail a waste of ground, because the space occupied by an open ditch cannot be covered by a crop, whereas the soil which overlies an underground drain can. The depth of drains and the distance between them will depend upon the character of the soil and subsoil. Ordinarily a retentive soil requires the drains at no great distance apart and not very deep, whilst deep drains at a considerable distance apart will effectually drain a lighter description of soil. A heavy clay with a retentive subsoil might be well drained by drains 18 feet apart and 3 feet deep, on the other hand a more friable soil might be made equally dry by drains 4 feet deep and 36 feet apart.

The main drain must discharge its water at least 6 inches above the highest level of the water in the *nála* or other outlet. Usually a main drain is $3\frac{1}{2}$ or 4 feet deep. The minor drains should be at least 3 inches less in depth and should discharge their water into the main drain at an angle considerably more than 90°. This facilitates an easy and continuous flow of water from the minor drains through the main drain. It is not expedient to have minor drains of greater length than 200 yards. Because, if drainage is essentially necessary the filtration of water into the drain pipes at the lower levels of the field will be obstructed by the water flowing in the pipes which probably nearly fills them, and this will be especially the case when the soil is wet to excess. Should the field be of a greater length than 200 yards a

central main drain is therefore necessary, and the following diagram will indicate the manner in which the field can effectively be drained.



A B C D	Field.
E E	Main drains draining water into *nála.*
F F	Minor drains.

The initial cost of underground drainage is usually heavy, but the capital expended may often be found a sound and profitable investment. The cost varies enormously with the character of the soil and subsoil and the ease or difficulty of getting drainage material and other conditions also affect outlay so that on paper the cost can only be approximated. In India with locally manufactured tiles cheaply made and by digging the drains with cheap cooly labour the cost need not exceed 30 to 40 rupees per acre. This outlay would almost exceed the agricultural value of land in some districts, but in others where canal water is available for irrigation thorough drainage fits the soil to grow valuable garden crops and the cost of drainage is recouped in a very short period provided garden crops can be grown successfully. Cost.

IRRIGATION.

Irrigation would appear to be the exact converse of drainage, but it is not so. In each case we aim at the free passage of water through the soil. Although the advantages of irrigation are recognized in most countries they are doubly so wherever the rainfall is scant and irregular. Water is of indispensable necessity to vegetable life, and an enormous quantity of it is required to sustain the vigorous growth of a cultivated crop. In tropical Irrigation is specially valuable in hot countries.

countries the largeness of the amount of water absorbed by vegetation is owing to the high temperature of the atmosphere which is far greater than in more temperate climates. In India, the cultivation of certain crops is never attempted unless an artificial supply of water for irrigation can be commanded. The successful cultivation of late or *rabi* crops depends upon favourable rain and dew, but too often a drought at this season disappoints the farmer and without an artificial supply of water his crop fails. Continuous drought is more disastrous on some soils than on others. Deep black land has the power to absorb and hold moisture to a greater extent than a lighter description of soil, but it is the lighter description of soil which is benefited most by irrigation. There can be no advantage in irrigating unless the water freely percolates through the soil. A soil to be irrigated to advantage must drain itself comparatively dry between waterings, otherwise irrigation will cause more harm than good. The water must at no time stand stagnant. Irrigation softens a soil and helps to extract plant food from comparatively insoluble soil material. It carries fertility to a soil, for no water is absolutely destitute of manurial elements. In the interval between waterings the soil contracts and crumbles. This alternation of contraction and expansion is beneficial. The atmosphere freely enters the soil pores as the water drains away and exercises an aerating power.

The general effects of irrigation on soils.

Some soils are suitable for irrigation, others are not.

There are soils which can be irrigated to advantage and soils which cannot. The fertility of deep clay land may be temporarily, if not permanently, lowered by irrigation particularly if the water applied is brackish in any degree. All soils which fissure to any extent in the hot season are more or less unsuitable for irrigation, but even this description of soil may, by means of heavy dressing of manure, be so changed in character, that in time it may become good garden land, but before irrigation is practised to any extent on such land the effect should first be tested on a small scale.

The interval between waterings depends upon the character of the soil.

Some soils dry quicker and require flooding oftener than others. In the Deccan medium black soil often grows irrigated crops. Generally a porous bed of *murum* underlies this kind of soil at depths varying from 18 inches to 3 or 4 feet. The shallow soil will require water at short intervals in small quantity. The deeper soil will bear a heavier flooding and take a considerably longer period to dry. In the neighbourhood of Ahmedabad the soil is alluvial sand of immense depth. This land has little or no power of retaining water, and cereal crops grown under irrigation get a light watering every fourth or fifth day in the hot weather. Elsewhere in Gujarat where the alluvial soil is more of a loam, water is seldom applied oftener than once in 6 or 8 days. If water is obtained on payment from an irrigation canal the rate charged is a per acre rate, and an excessive quantity of water is generally used. If, however, the water is drawn by the cultivator from his own well, his

interest is to apply just enough water as often only as is necessary. The quantity of water required for crops grown under well irrigation will vary with the description of soil, *i.e.*, whether very absorbant or otherwise and with the kind of crop grown, *i.e.*, whether it is vigorous growing and succulent or the reverse.

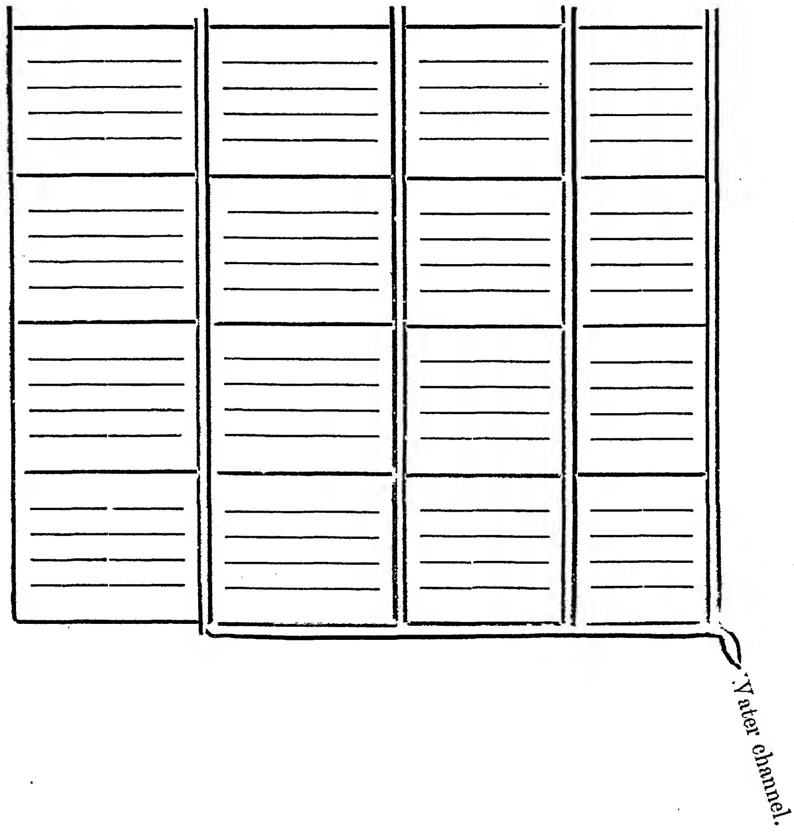
Some irrigated crops require much more water than others.

A crop of sugar-cane, of plantains or of fodder-*jowári* will require much more water than potatoes, ginger, turmeric, onions or any ordinary garden crop, and these in their turns require considerably more than wheat or gram or ground-nut. The three latter named crops are grown often partly as dry crops and partly irrigated. An occasional flooding at intervals of three weeks or so being given as the crops approach maturity. Ordinarily in the Deccan all garden crops get water on an average every tenth day in the cold season and every seventh or eighth day in the hot weather. But a succulent vigorous growing crop like sugar-cane gets at each watering, twice as much water as ginger or potatoes. A full watering for sugar-cane is equal to about 2 inches of rainfall. Experiments at Mánjri have proved that the best possible results with sugar-cane were obtained with fairly light frequent irrigation. Thirty-three waterings were given in 12 months. Only a few waterings were required in the monsoon, the rainfall having been approximately 30″ between June and November. The 33 waterings were equal to a rainfall of 50″.

The method of laying out land for irrigation.

The cultivator of garden land is exceedingly expert in preparing his field for irrigation. The land when ready for planting is clean, well pulverized and friable to a considerable depth. The field is marked with exactness so that beds of any required size can be formed. The size of these beds vary, but a common size for garden crops like ginger is 12 feet by 6 feet. This space is embanked by raising a ridge round each bed. In the compartment thus formed the crop is sown or planted. It is necessary to run a furrow between each double line of beds. This furrow will form a channel for the irrigation water. The beds right and left of this channel may be watered in turn by temporarily breaking the ridge which surrounds a bed and blocking up the water channel with the earth thus moved. The water is allowed to flow into the bed until it is sufficiently irrigated when the water may be similarly directed into the opposite bed or the next adjoining one. For sugar-cane the water compartments are generally arranged differently. The field is ridged with a native plough. The furrows are made as deep as possible and the ridges are 24″ to 27″ apart. Furrows 10 feet apart are made by the plough across the line of ridges, and the soil thrown up by the plough on either side of the furrow is further raised by earth cut away from the disected ridges. Every fifth ridge is earthed up also by hand and these form the lateral bunds. Whilst the cross water channels by means of their earthed-up sides furnish the end-bunds for each compartment. In this

manner the field is divided up into a number of compartments about 10 feet square. Each is as deep as possible so as to hold a good deal of water at each flooding and each contains 5 furrows and 4 short ridges. The cane is planted in the furrows. The following diagram shows the arrangement of water compartments and water channel in a sugar-cane field :—



Irrigation of lucerne.

Some crops such as lucerne (Medicago sativa) or potatoes do not thrive if the stems are for any time in contact with standing water. The difficulty is overcome if the crop is planted on ridges and the irrigation water is run along the furrows. This plan can only be adopted on tolerably level land or at least only if the furrows have a gentle fall from their upper to their lower ends, if otherwise the upper portion of the field is imperfectly watered whilst the lower levels are excessively flooded ; moreover the water gains such force by its own velocity that manure and soil are carried along the furrows from the upper to the lower levels. There are

other ways of distributing irrigation water which will be described under the heads of crops, to which the methods apply.

In irrigating fruit trees it is usual to have a regular system of water channels along which the water is led. A *thala* or saucer-shaped bed about 8 feet in diameter surrounds each tree, these beds are periodically dug and manured. A gutter is cut from the *thala* to the nearest channel and the bank of the water channel temporarily broken to admit the water to the gutter and thence to the tree. If the trees are planted in straight lines one gutter may serve for many trees.

Irrigation of fruit trees.

All waters are suitable for irrigation except those which contain in solution substances poisonous to vegetation. Such waters are rare, but the drainage from peat swamps, ore beds and mineral springs might be unsuitable for this reason. The water of streams or *nálas* might be polluted by impurities from chemical and other factories so as to be unsuitable for irrigation. Brook or river water is considered superior to well water on account of the greater percentage of fertilizing material held in solution or in suspension. Water containing suspended silt is specially valuable, but clear water conveyed by channel from a canal or bunded stream is sometimes held in poor repute by cultivators as compared with well water because it is "cold." Sometimes as in Gujarat the water of particular wells is appraised at a high value for particular crops and justly so. There are many brackish wells throughout the alluvial tracts of Gujarat which on account of the alkaline salts contained in the water are much valued for tobacco culture. For many years consecutive crops of tobacco have been raised on fields near Nadiad and also at Petlád with no other manurial assistance except that derived from the brackish water used to irrigate the crops. These waters owe their fertilizing power to nitrates of potash and lime and other salts.

Waters most suitable for irrigation.

Irrigation is said to be exhaustive, and so it is in this way that it stimulates a soil to produce a heavy crop at the expense of inherent fertility. If, however, it is practised in conjunction with liberal manuring the natural resources of the soil need not be impaired. If manure is not applied in fair quantity exhaustion will occur sooner or later, and the fertility of the soil is lowered in a manner which is not legitimate. Light sandy soils will become exhausted sooner than those of a heavier description.

Irrigation has an exhaustive effect on soils.

Land is irrigated either by water led by gravitation from tanks, lakes or any other reservoirs or from water dammed back by a bund thrown across a river, or water for irrigation may be raised from wells by the lifts in common

Water-lifts.

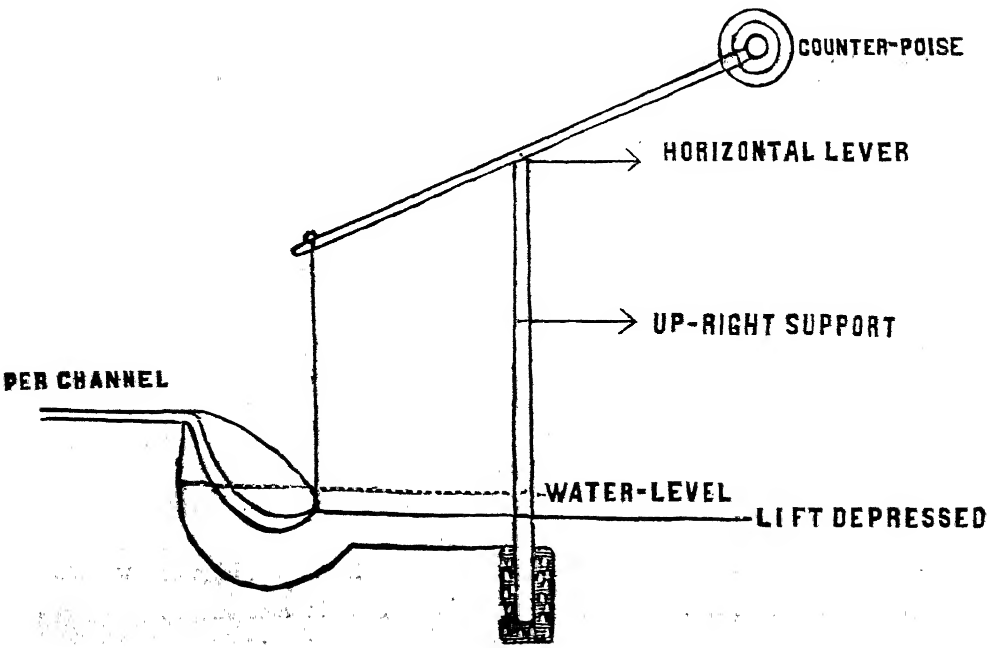
use. The lifts mostly used throughout the Bombay Presidency are varieties of the leather bag, known in the Deccan as a *môt* and in Gujarat as *kos.*

In the coast districts of Bombay where the depth of water in the wells is small the Persian wheel is largely employed, and its use is general in Sind. In the Karnátak a hand lever and bucket lift is used in wells.

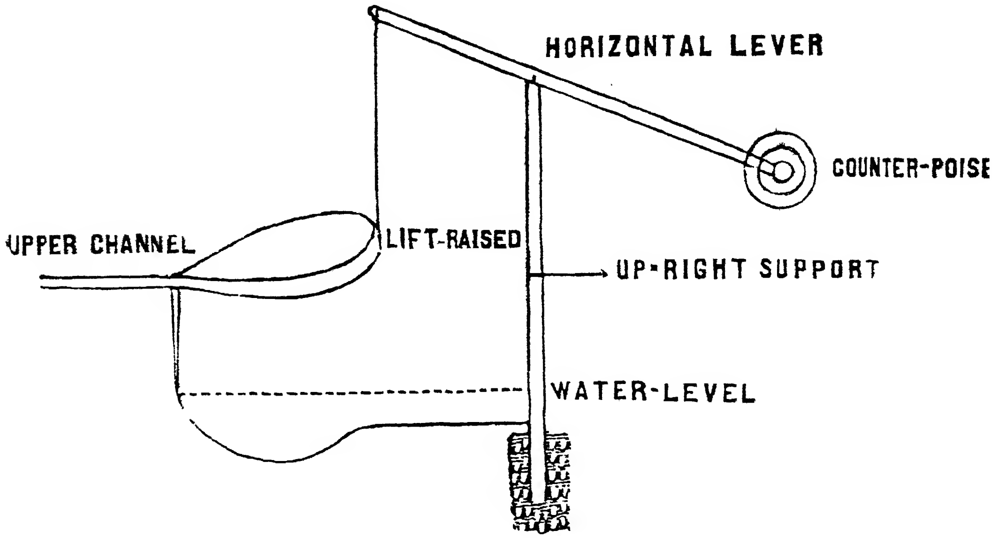
COUNTER-POISE WATER-LIFT.

Lát—Konkan, *Chadasia*—Gujarat.

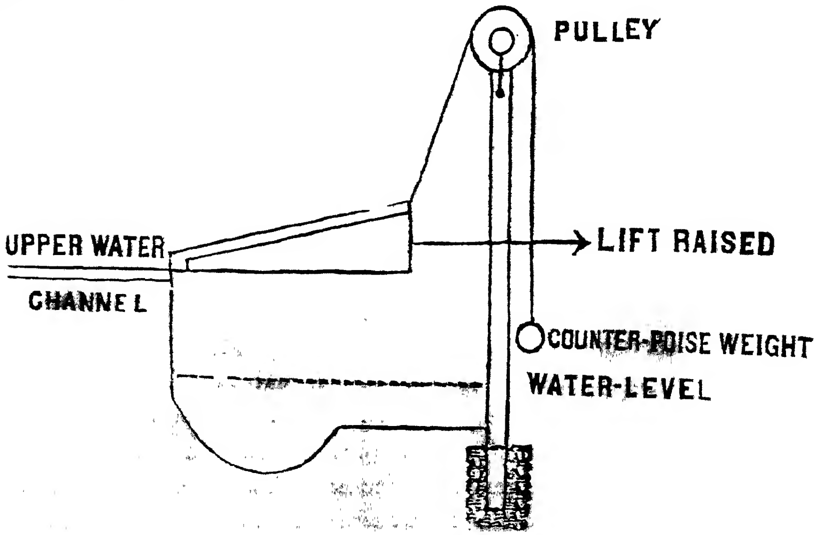
The lift consists of leather stretched upon a boat-shaped frame, suspended by a rope to the end of a horizontal pole which is carried and evenly balanced on a stout upright support on which it works see-saw fashion. The other end of the horizontal pole carries a counter-poise weight. The lift is used to lift water 5 or 6 feet from one channel to another or from a tank into a water-channel. The narrower end of the boat rests upon the higher channel and is so secured to it by a through rod which acts as a hinge that it delivers water into the channel as the lift is raised and cannot get out of position. The other wider and more capacious end is alternately depressed and raised. When depressed it fills with water, when raised the water flows into the upper channel.

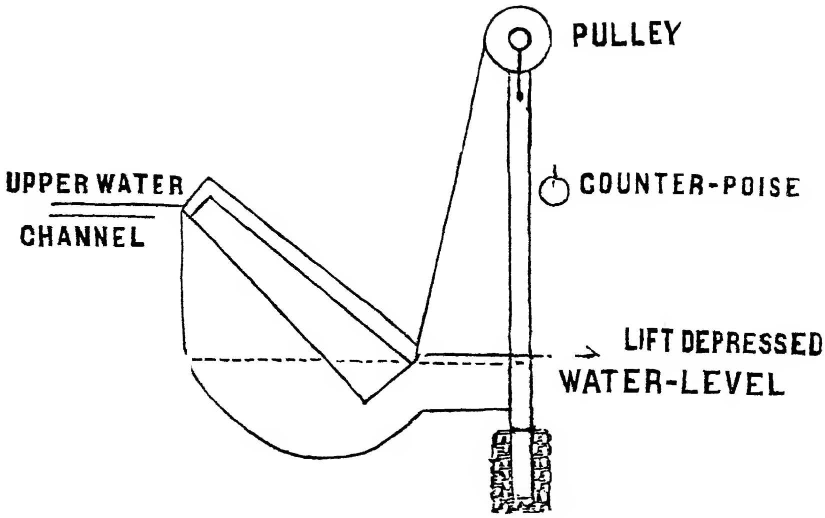


The counter-poise is of such weight that no great exertion by manual power is required to depress the lift and when the lift is sufficiently filled no great force is required to raise it. It is worked by one cooly and largely used in districts west of Ahmedabad.



Sometimes a wooden box is used instead of a leather-boat. In which case the box is open at one end, about 8 or 10 feet long and made deeper at the closed end as shown in diagram. It is depressed and raised alternately by means of a rope working over a pulley, the free end of the rope carrying a counter-poise weight.





Irrigation by môt in the Deccan.

Well irrigation is termed in the Deccan *motasthal bágáyat*, and the following descriptions of the construction of wells and of the *môt* are taken to a considerable extent from Fletcher's "Deccan Agriculture."

Wells used in irrigation are circular and 8 to 16 feet in diameter and vary in depth from 8 to 50 feet. The average depth may be put at 25 to 30 feet. The wells are usually pitched with dry cut stone very frequently only on the side on which the bucket is worked. Wells of large diameter with a sufficient supply of water may accommodate 4 or more water-lifts, half the number being worked on opposite sides in which case the well is pitched all round. The water is raised in leather buckets which are of two shapes the one self-discharging, the other not. Either is called a *môt* in the Deccan. The self-discharging *môt* is a leather tube which may vary in length from 6 to 10 feet. One-half of the tube is wider than the other half. The wide half is 18 inches to 2 feet in diameter and is distended at the mouth by an iron ring. The other half is much narrower and is not distended. Two stout bars are securely fixed to the ring across the mouth of the bucket at right angles. A stout rope is attached at the intersection of these bars. The other end of this rope is passed over a pulley fixed almost directly above the lip of the receiving trough and about 4 feet above the top of the well. A second thinner rope is fastened to the smaller mouth of the bucket in a manner which will not obstruct the flow of water through the small mouth. The other end of the thin rope is passed over a roller which works on the lip of the receiving trough. These two ropes are attached to the neck-yoke of a pair of bullocks.

and their lengths are adjusted so that the narrow half of the bucket doubles up alongside the broad half, and the two mouths are level with each other as the bucket ascends or decends in the well. In raising the bucket the draft animals walk down a slope which is often artificially dug out. This plane is as long as the well is deep. The incline makes the draft easier and also facilitates quick work because the bullocks walk quickly down the incline. When the full bucket reaches the top of the well the narrow mouth follows its own rope over the roller and delivers the water into the receiving trough, whilst the broad mouth is by means of its rope carried to the pulley four feet higher up. This ensures that the bag is completely emptied of water Four bullocks are required to raise water by means of a self-discharging *môt* of large size which, however, is only used in deep wells. The smaller size would not keep up a sufficient stream in the channel which conveys the water from the receiving trough to the field. The outlet from the receiving trough is sufficiently large to allow the trough to empty itself as fast as it is filled and small enough to keep up a continuous flow of water in the channel which it feeds. As supplementary to the foregoing, I have taken various exscripts from Mr. Beyt's description of the same practice in Gujarat. There water from wells or rivers is very generally raised by the *rámio* or *sundio kos*. The *rámio kos* is a whole bullock hide with the corners cut off, pursed with leather thongs to an iron ring 18 to 24 inches in diameter which holds from 4 to 7 cubic feet of water. The bag is brought up by a rope working over a pulley and attached to the neck yoke of a pair of bullocks descending a slope. On the bag reaching the level of the discharging trough it is bumped down and collapsed by an attendant who is stationed there for the purpose. He gives a signal to the bullock driver who at once detaches the rope from the neck yoke by pulling out a toggle or pin. The bullocks on being detached at the bottom of the decline turn round and walk up to be reattached to the rope, the bag, meantime, is thrown over the lip of the well by the attendant and descends by its own gravity. The *sundio kos* is identical with the Deccan *môt* already described and with this lift the bullocks are not detached. They have to slowly back up the decline. This is very wearing work for heavy bullocks and ordinarily medium sized active bullocks are employed. A *sundio kos* is only used in wells of moderate depth, *i.e.*, when the depth to water is not more than about 35 feet.

The ramio kos and sundio kos of Gujarat.

A *môt* of ordinary size discharges each time about 30 gallons. If the water is reached at a depth of 30 feet one bucketful will be discharged every minute. The interval between each delivery is most regular and rarely exceeds 65 seconds. If a working day is taken as 9 hours then the number of gallons raised in that time would be $30 \times 60 \times 9 = 16,200$ gals. $= 162,000$ lbs. = approximately 72 tons. Unless the water channels are *pucka* built there will be considerable leakage before the water reaches the field, particularly if it is at any distance—5 tons of water may

The amount of water raised by mot in a day.

be lost in this manner per day. This will leave 67 tons available for irrigation. If this quantity be distributed over an acre of ground it would be approximately equivalent to $\frac{2}{3}$ of an inch of rainfall. Sugar-cane requires at each time of watering water equivalent to at least 2 inches of rainfall. Consequently under the conditions named one *môt* would supply enough water to irrigate one acre of cane in three days, or supposing cane has to be irrigated on an average once in 8 days one *môt* would supply water sufficient for $2\frac{2}{3}$ acres; whilst of other garden crops requiring less water $3\frac{1}{2}$ to 4 acres might be sufficiently irrigated by the same power.

The double mot.

A double *môt* works satisfactorily when there is an ample supply of water in the well. One bag ascends whilst the other is being lowered. The rope attached to the descending bag is being unwound from a drum whilst that attached to the ascending bag is wound thereon. The drum turns on its vertical axil by a lever to which the bullocks are attached. It is a primitive style of roundabout gear. The draft is in one direction until a bag delivers its load. The bullocks are then turned round and go the opposite way and thus give the drum a reverse motion which unwinds the rope of the bag that has delivered its load and allows it to descend to the well to be refilled whilst at the same time the rope of the other bag is being wound lifting the bag therefore to the surface to be discharged in its turn. Theoretically in comparison with the single *môt* double the water should be lifted, but in practice this is not the case because one bag descends no quicker than the other ascends and the work bullocks move much quicker down an inclined plane than in a roundabout gear.

The Persian wheel.

The Persian wheel is worked by a roundabout gear. The lever to which the bullocks are yoked gives motion to a horizontal toothed disc which through the medium of a rude cog wheel turns a drum which carries an endless rope ladder. To this ladder a number of earthenware pots are attached, each being distant from the next about a foot. There may be one, two or more tiers of these on the same ladder. The pots come up full and discharge their contents as they pass over the drum. A shoot or receiver is so placed that it catches as much as possible of the water as it is emptied from the pots which inverted and empty are carried down again to be refilled. The power wasted by quantities of water falling back into the well is considerable. A manual Persian wheel is worked by one, usually two men, who tread the rounds of the sparred drum in a tread-mill fashion. Thus the rope ladder with its load is carried round.

The endless chain pump.

The endless chain pump acts much on the same principle as a Persian wheel. It is a simple and inexpensive contrivance for raising water. A pulley is keyed on a shaft which gets motion from an ordinary roundabout gear. This pulley carries an endless chain. The chain having discs on

it at intervals of a foot is made to ascend through a tube which descends from the top of the well to two feet below the surface of the water. The discs are about the same diameter as the tube and consequently carry upwards a volume of water which is in ratio to the size of the tube. The pulley which carries the chain carries it round because the discs on the chain fit into corresponding notches on the rim of the pulley. Two or more of these motion pulleys can be keyed on the same shaft, so that two or more chain pumps can be worked in the same well, by the same gear, if the supply of water warrants the additional outlay. According to Colonel Hallen, late Inspector-General, Civil Veterinary Department, a double chain pump with 2 four inch pipes can lift about 5,000 gallons per hour or 138 tons per day of eight hours from a well, the depth to water being 20 to 25 feet. The chain pump will not work satisfactorily in deep wells with depth to water 35 or 40 feet. The escape of water back to the well past the discs as they ascend is such that no water would be delivered at the surface in the case of a very deep well. The draft as shown by a dynamometer will increase with the depth of the well, but for any depth the draft of a roundabout gear must of necessity be a great deal less than that required to pull up a dead weight of water by sheer strength.

Dhekudis in Gujarat are water-lifts erected on the banks of rivers. The *rámio* and *sundio kos* are used. The water must be found underneath the verge of the high perpendicular banks or be led there from the bed of the stream.

When water has only to be raised a few feet this is done by the *jhil* lift of Gujarat which is identical to the apparatus known as *dol* in the Deccan. A large shovel like scoop is suspended on a tripod and swung by means of ropes by two men. Each swing catches some water and throws it into a channel at a level three or more feet higher. A smaller basket scoop swung by two men without any tripod support is sometimes used to lift water two or three feet from one channel into another one. This is used when the nature of the ground prevents the water being carried by gravitation to a part of a field that lies at too high a level to be otherwise irrigated.

LIMING LAND.

Limestone is common in many parts of the Bombay Presidency.

Limestone and marble each of suitable description for building stone, are quarried in various parts of India. In the Bombay Presidency there is no marble, but very good limestone is found in the Panch Maháls. It is also common in a less pure form all over the Presidency. The lime used for mortar is obtained commonly from *kunkar* or concretionary nodules of limestone. The lime thus obtained has usually hydraulic properties, *i.e.*, when

such limestone is burnt the burnt lime when made into mortar or brought into contact with much water sets very hard, and on this account is less suitable for agricultural purposes than that obtained from the Panch Mahál quarries. Ordinary limestone contains about 80 or 90 per cent. of carbonate of lime, also usually carbonate of magnesia, oxides of iron, and manganese, silicate of lime, phosphate of lime, &c. The presence of some of these so called impurities adds to the agricultural value of lime. Carbonate of magnesia in excess, however, is harmful, because of the hydraulic properties which it imparts.

Lime is an essential plant food and an active manure.

Lime is an essential plant food. In most countries it is considered a powerful and active manure. Its use as such in India is unknown by ordinary cultivators.

The agricultural operations known as chalking or marling are useful chiefly because carbonate of lime is thereby added to a soil. Lime is, however, more commonly applied as burnt or caustic lime.

The chemical changes which are induced by burning lime.

Limestone, by burning, undergoes a remarkable change. If sufficient heat is applied, the water of combination is driven off, also carbon dioxide, and calcium oxide remains as a light porous cinder which is called caustic or shell lime. It has properties very different from limestone rock. It is corrosive in as much as it burns organic matter with which it comes in contact. It has a hard indestructible appearance, yet, if water is added to it, it falls to an impalpable dry powder, a considerable degree of heat being meantime evolved. The water has combined with the lime oxide to form hydrated oxide of lime or slaked lime. This change will occur gradually if caustic lime is exposed to the moisture of the atmosphere, beause caustic lime has a great affinity for water. Caustic lime also gradually enters into combination with carbon dioxide, and excepting that it is in a very fine state of division, it has practically the same composition as limestone before being burnt.

Lime burning described.

Limestone is burnt generally in a lime kiln, sometimes in an exposed heap. The latter method is common in India. The fuel used is whole cowdung cakes, also coal and charcoal. The limestone, if it is not nodular, is broken into medium-sized easily handled fragments and is built up into a cone-shaped heap in alternate layers with the fuel. The fuel layer next the ground should be of considerable thickness. A heap of fuel 4 feet in height and of equal diameter should occupy the centre of the pile. When lit the cowdung burns slowly, but at the same time gives out sufficient heat to burn the limestone thoroughly. Lime shells prepared in this manner ought to have a special value for application to land, owing to the manurial value of the cowdung ashes. When limestone is burnt in a kiln, coal or charcoal is the fuel used. The limestone and the fuel are arranged in alternate layers and when the kiln is full the lowest layer of fuel is lit.

There is no doubt that the injudicious application of caustic lime tends to exhaust a soil, because it hastens the decay of organic matter, and exercises upon the mineral matter a decidedly solvent action, whereby the alkalies, potash and soda are set free from their more or less insoluble silicates. A heavy application of lime is only justifiable if the farmer intends to maintain the fertility of his land by an inexhaustive system of cropping, and by liberal applications of manure. Under these circumstances the effect of lime is to stimulate the soil to increased fertility, but under any other conditions there is too much truth in the common saying, "Lime enriches the father but impoverishes the son." The effect of lime is believed to last for a considerable time and usually it is not applied oftener than once in 20 years. A heavy application can be given with advantage to deep glutinous clay soil, whilst lighter descriptions of soil require much less. Caustic lime sets free ammonia from nitrogenous manures. Therefore it should not be applied at the same time or indeed in proximity to manures containing salts of ammonia. Caustic lime, if brought in contact with farm-yard manure or any other organic manure, would hasten the decay of the organic matters too speedily. Probably lime exercises its most beneficial influence on recently reclaimed peat lands, which, if previously drained, may be ameliorated in a most striking manner by the application of lime. The humus which exists in excessive degree quickly decays. Harmful organic acids are neutralized and the tough consistence of the peat is reduced so that it becomes friable and easily tilled.

The use of caustic lime as manure.

Lime should, if possible, be applied during the fair season; at any rate when rain falls, liming should be discontinued. A heavy application would be 7 to 9 tons per acre; a light dressing 2 to 3 tons per acre. It is important that the lime be equally distributed over the surface. It is difficult to effect this properly in the case of a light dressing, and therefore it is usual to mix the lime previously with earth or any waste vegetable material. The compost thus prepared being of considerable bulk can easily be distributed equally over the surface of a field. If a heavy application of lime is given, it should be carted direct to the field and unloaded in small equi-distant heaps. The lime, if not fully slaked, if exposed thus for a few weeks, will absorb moisture and carbon dioxide from the atmosphere, and will crumble to a fine powder. In this condition it can be evenly distributed. Lime is soluble to a certain extent in soil water and therefore has a tendency to sink in the soil. It, therefore, ought to be ploughed in with a light furrow or mingled with the soil by the use of the harrow.

The season and method of application.

Lime exercises a better effect upon pasture grass than perhaps upon any other description of vegetation. A material improvement of the natural herbage has been often traceable to the effect of lime. Clovers and other leguminous plants take the place of coarse grasses and worthless plants.

Application of lime to pasture land.

Useful effects caused by lime.

It is well known that a heavy liming obviates the tendency of some cultivated plants to become diseased, and in addition to other effects already noted nitrification is promoted and the physical character of a soil improved. The consistence of clay is improved by lime, likewise that of sand—a clay soil becoming less adhesive, whilst a sandy soil more dense and therefore more retentive of moisture and manure.

TILLAGE AND TILTH.

Tillage assists the disintegrating agents of nature in pulverizing soil particles.

The farmer stirs a soil with a plough, works it with a harrow, and crushes the clods with a roller, in order to prepare a favourable seed bed. The soil may be loosened, by effective tillage to a considerable depth. The more a soil is stirred by mechanical means, the more freely are its particles pulverized. The disintegrating agents of nature, if they have free scope to act, will pulverize the soil particles much more effectively than any tillage implement can ; but the farmer must assist nature. The soil must be loosened and exposed to the influence of the atmosphere and other natural agents. The greater the penetrating power of a plough and the more thoroughly it stirs the earth-layer which it penetrates, the more perfectly are the soil particles exposed to aeration and other beneficial influences. The term "good tilth" implies that the soil has been well stirred, that the tillage operations, to which it has been subjected, have eradicated weeds, that the soil is smooth and friable to a considerable depth—a condition which is favourable to perfect germination of seed, and that the soil has been brought into the best possible condition to conserve moisture and to allow the free ramification of roots. A free-working and open soil in a good state of tilth permits the free circulation of air and moisture through it, and also allows the delicate rootlets to penetrate the soil in all directions to collect an abundant supply of plant food. There is no question that deep tillage enlarges the store-house whence plants obtain nutrition and also increases the supply of available plant food, because the earth particles are more exposed to the influence of nature's dissolving agents.

Deep tillage not so necessary in India as in some countries for reasons given.

If land is left untilled the upper layer becomes so consolidated that the free percolation of air and water is obstructed and, moreover, weeds soon establish themselves. The induration referred to is especially noticeable in any description of soil found in countries of temperate climate. In India, however, the effect of the extreme high temperature of the hot season followed by a heavy downpour of rain during the monsoon is such on some kinds of soil that it is impossible that the upper stratum can become consolidated except for a season when it does not matter. The deep beds of black clay which occupy immense tracts in India harden annually during the fair season. These soils possess in a high degree the powers of expansion and contraction.

They contract during the hot weather and fissures which are wide and deep are thus formed. Under the influence of a burning sun, an inch or two of the surface becomes friable, and this friable layer may be increased, as it often is, by the use of the native harrow. The harrow scrapes and loosens a little of the underlying hard layer, and owing to the action of the implement a good deal of the friable surface soil filters into the gaping cracks; and thus every year a fresh layer of soil is exposed for the reception of seed. Under this system of tillage, a layer of soil probably 4 feet or more in depth is slowly undergoing inversion. In time soil particles existing 3 or 4 feet deep in the subsoil will gradually reach the surface.

The objects aimed at in ploughing black soil deeply in the "fair" season.

I do not wish to imply that black land does not need ploughing. On the contrary deep ploughing is absolutely necessary to keep this description of soil free from deep rooted weeds, and to be effective should be done in the fair season. A well constructed native plough will on this description of soil do good work, when an English plough will not enter the soil, much less turn a furrow. The soil would be turned up into huge clods which encase the trailing underground stems of *kunda* and *hariali* or other deep rooted grasses or weeds. The lumps are baked by the sun, and the weeds perish though actually not exposed on the surface. If the roughened surface could be seen by a farmer of heavy clay land in England, he would apprehend some difficulty in pulverizing it. The heat of the sun alternating with the chill of night breaks the cohesion of the lumps, and with the first shower of rain, the whole falls to a thoroughly pulverized condition.

The advantages of good tilth.

Tilth is a condition which depends to a great extent upon natural conditions in India. Unlike other countries a small degree of judgment is required to produce a fine friable condition of soil at sowing time. If after the burst of the monsoon the farmer refrains from working land previously ploughed, whilst still wet the combined effect of sun and rain, and judicious tillage, when the soil is sufficiently dry, produce a most satisfactory seed bed. Every practical farmer knows that the preparatory tillage necessary for different crops should vary to a very considerable extent. There is a decided advantage, if the seed, when sown, is deposited in a smooth moist friable layer of soil, in which the seed will rapidly germinate. Moreover, if this layer has good tilth, the delicate rootlets of the young seedling will rapidly strike into the soil and seek after nourishment, and the leaf stalk will ascend with equal rapidity to unfurl its leaves by which sustenance is obtained from the atmosphere. On the other hand if seeds are sown in a badly prepared seed bed, they germinate slowly (many do not germinate at all), and the plants make slow progress both as seedlings and afterwards. The rootlets of a young plant are far too delicate to force their way through soil which is not well pulverized, and which by tillage had not been thoroughly opened up.

A firm seed bed necessary for some crops. A deep loose seed bed desirable for others.

Wheat and *jowári* and some other cereals prefer a firm seed bed. This does not imply that deep ploughing does not benefit these crops. It means rather that the plough should not be used immediately before seed time. Although the seed bed should be firm, the upper layer to a depth of about 3 inches should be "smooth as an onion bed." There are other implements besides the plough which are very well adapted to compass the desired degree of friableness. For other crops notably potatoes and all root crops, the porous friable layer should extend to a depth of 6 or 8 inches at least, and to secure this degree of tilth, probably a plough is the best implement to use; but judgment is required to determine when it can be employed with advantage. The soil must be sufficiently moist yet not too wet. Otherwise deep stirring, or in fact any working, especially in clay soil, will cause the earth particles to stick together to form plastic lumps which on exposure to the sun or air harden into brick-like pieces, which it is difficult afterwards to pulverize for some time.

Interculture.

Tillage should not cease at seed time. All crops are considerably benefited by bullock hoeing and hand-weeding. These operations not only suppress weeds, but conserve moisture. Moreover, the surface of all soils, and more particularly heavy clay soils, cakes and hardens after a tropical downpour of rain, and when broken up by hoeing, the hardened layer is pulverized, air enters into the soil and the succeeding showers freely percolate into the soil, as the rain falls. Frequent stirring of the surface soil, during the early growth of almost any crop is specially valuable, because it accelerates nitrification which as already stated proceeds under certain conditions most energetically near the surface.

WARPING.

The water of rivers in flood is discoloured by fine earth particles held in suspension. The Indus, when in full flood, inundates vast tracts of land in Sind, and its waters annually deposit a layer of fine mud on land which at other seasons is under cultivation. This sediment adds to the depth of alluvium deposited in previous years, and the fertility of the land which the Indus inundates is maintained by nature's system of warping. Similarly the fertility of the Nile Valley is maintained by the annual rising of the river. Artificial warping differs from the natural formation of alluvium only, in that the water of a turbid stream may be diverted from its course, and held in a particular area sufficiently long to deposit a layer of sediment, and if the process is often repeated, a soil of considerable depth may be formed on rock or any other sterile area. Many of the small rice fields on the Ghâts have been formed by throwing *bandháras* across the turbid hill streams and either diverting the water or allowing a small lake to form above the weir. In this

way the current is so obstructed that suspended earthy matter is deposited, and in time the silt layer becomes so deep that a rice crop can be raised thereon. The lower terraced rice fields of the Gháts are annually warped and improved by the silt carried down by the drainage water of the uplands. Light sandy or gravelly soils may be materially improved by the addition of warp, which usually is fine friable homogeneous loam. But there are exceptions. For instance, the annual uprising of the Tapti usually adds a fine deposit of fine mud to the *bhátha* lands situate on the shelving banks of the river. Sometimes sand and gravel is deposited in places on good *bhátha* land and its agricultural value is thereby lowered at least temporarily. The next flood may remove the objectionable material or deposit a super layer of fine mud.

CLAY BURNING.

This is a costly operation undertaken occasionally for the specific purpose of ameliorating the dense adhesive character of a stiff clay soil. If the work is properly done, the soil becomes more easily tilled, because its texture is improved. The heat exercises other effects also. It has a solvent action upon certain mineral constituents. In particular, it liberates potash and soda from their more insoluble silicates, and in other ways increases the percentage of soluble mineral material. On the other hand organic matter is burnt and nitrogen dissipated. The benefits of burning are greatest when the clay soil contains a fair proportion of lime. The heat may be sufficient to convert part of the lime into its caustic form.

Burning has a chemical as well as mechanical effect on clay.

If clay is puddled, moulded and exposed to the sun in India, *kacha* bricks are made which do not readily crumble on exposure to weather. If the puddled clay is subjected to a high temperature it sets into a hard mass, which is as indestructible as the hardest stone. Furnace-burnt bricks can be pounded to dust, but this dust has no plastic properties. It has no more consistence than sand and contains no elements of fertility. If clay is smother-burned at a low temperature, its particles lose cohesion, and its fertility is improved rather than destroyed. If therefore a proportion of the surface soil of a clay field is burnt in this manner, and the remaining ash is mixed with the unburnt clay, the friableness of the soil is improved in the same way as if a similar proportion of sand was added, whilst the soil is chemically changed by the heat in the manner already referred to. Clay if properly burned loses all plasticity, and the remnant ash is a friable dull red or brown powder, which when soaked with water has no more adhesiveness than brick dust.

Clay should be burnt at as low a temperature as possible.

The method of clay burning.

Clay burning should only be carried out in the fair season. The field should have been previously ploughed, so that the surface soil can easily be collected in lumps of moderate size. Fuel in considerable quantity is required. Brushwood and ordinary firewood are generally used. A considerable quantity of fuel is laid for a fire and heaped over with clay. The fuel is then fired and when well alight, more clay is added to the heap, and this is repeated as often as smoke is seen to issue from the heap. The object is to keep the fire in subjection, so that the heat is slow and steady, and the clay become charred rather than completely burnt. The heaps when large enough are allowed to burn out and when the whole field has been gone over, the ashes are equally distributed.

Advantages.

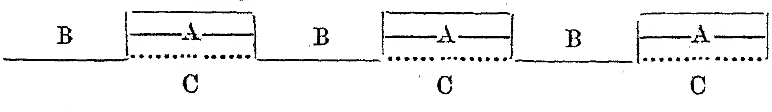
The chief advantage of clay burning is undoubtedly the mechanical improvement of the soil, but the chemical improvement, notwithstanding the loss of organic matter and nitrogen is also considerable. Weeds are to some extent destroyed, also the larvæ of destructive crop pests.

PARING AND BURNING.

This is an occasional undertaking on an English farm, and rather a good plan for getting land, that has been long under grass into a fit state to be easily ploughed and cultivated. If there are many deep-rooted weeds and at the same time a thick mat of grass, the excessive number of fibrous roots, and the toughness of the sward interfere with tillage operations. The difference between *clay burning* and *paring and burning* is that the latter is more wasteful. It is confined to burning a thin layer of the upper soil, seldom more than $1\frac{1}{2}''$ in thickness, the object being to get rid of weeds rather than to improve the mechanical or chemical condition of the soil. The first operation towards cleaning and cultivating old grass land, or land that has been some years under perennial grasses, or other perennial crops is to pare off the surface turf and burn it. The paring is done in the cheapest and most satisfactory manner with an ordinary plough having a broad share. The process is known by the names of "Raftering," or "Double raftering" or "Roll raftering."

Single and double raftering.

The following diagram will explain :—



The track of the plough is shown by the furrows B B B. The lines A A A. represent the original surface of the field, and the furrow slices of pared turf, removed from the furrows B B B are laid by the mould board of the plough on this surface. This is *single raftering*. If another plough

follows immediately behind the first, and its broad share cuts through the dotted lines, its mould board will turn over two layers of turf with the grassy side of each sandwiched in the middle. In this manner the field is *double raftered* or *roll raftered*, and thereby the turf layer over the whole surface is cut clean away from the soil. An expert ploughman with a steady tractable team will do this in a thoroughly efficient manner.

Burning the turf.

If there is dry weather for a fortnight the turf will be in a condition to be harrowed which will break it up and free it from a good deal of earth, and after two or three days' exposure to the sun it will be ready for burning. A little straw and brushwood is used as fuel to begin with. When a fire is fairly started, turf (collected by being raked together or thrown towards one centre by a pronged fork from a radius of six yards or so) is added to the fire. Care is taken that the additions are gradual to begin with. When a good sized heap is fairly alight more turf may be added as often as smoke appears. The first lit fires furnish burning material to light those subsequently burned. A good deal of practical experience is required to conduct the process of paring and burning properly. It must be the object rather to scorch the earth than to burn it, and to char the vegetable matter rather than reduce it to ashes. Earth should be added to each burning heap—the last thing every night—so that the fire does not break out into flames before morning. It is quite common for farmers to stifle-burn the grassy turf of roadsides or which is found in bye-places with the object of getting sufficient "ashes" to mix with artificial manures. The mixture ensures thorough distribution over the manured area, while the "ashes" themselves have a recognised manurial value.

Advantages.

Although paring and burning is an expensive process, it effects a saving in time and money in bringing a very weedy field into a culturable condition. There is no doubt that organic matter is lost, but the soil has been at the same time mellowed and improved by being burnt, and the ashes that remain contain a good deal of mineral matter in a condition that plants can at once appropriate. There is some reason in getting rid of the roots and stems and seeds of weeds, difficult otherwise to destroy. The eggs and larvæ of destructive crop pests are also destroyed, and the loss of organic matter and nitrogen need not therefore be much lamented.

MIXING.

Objects aimed at in mixing soils.

The processes known as claying, chalking, marling may be all classed under the above head. The object of either of these operations is to improve a soil having an excessive proportion of either clay or sand or lime. Conspicuous physical defects are improved by "mixing." Loams or soils that

are mixed by nature and are usually productive, because the clay, the sand, the lime, and the organic matter which they contain are mixed in proper proportion. The nearer we can bring a soil to the character of a loam, the greater will be its producing capacity. The advantage of mixing is illustrated in nature, first by the invariable fertility of alluvial tracts, second by the character of the surface soil where two strata of unlike character crop out at the surface and get intermingled.

The kinds of soils which are most improved by mixing.

A heavy clay would be much benefited by the admixture of sand and *vice versa*. But although a little clay will alter and enrich a poor sand it takes an immense quantity of sand to effectively change the plastic qualities of clay. It is not necessary always that the process of mixing should require transportation of material from a distance. Often the required material may be found in the subsoil, and by trench ploughing or by some mechanical means it can be added to the surface soil. It is, however, necessary to be sure that the subsoil contains nothing injurious to vegetation, as clay subsoils too often do. If admixture in the manner described is not practicable, then two fields of different character may be found sufficiently near to each other, so that their soils may be interchanged in such quantity as to effect a mutual improvement.

Marling and chalking.

Marling and chalking not only improve the mechanical condition of some soils, but also exercise a manurial effect on account of the phosporic acid and lime they contain.

The mixing of soils is done in India.

Mixing is not unknown in India. Clay is often carted from rice fields in sufficient quantity to add a layer one to two inches thick on sand land. The addition changes the consistence of the sand, so that it becomes better suited for sugar-cane and other garden crops raised under irrigation. The cultivator appreciates the value of tank mud, and in those districts where these water reservoirs are common, they are cleaned out with the utmost care and regularity each year. The silt which has collected in these tanks being the washings of village sites and cultivated fields, has some manurial value, and applied as it is at the rate of 40 cartloads or more per acre, adds considerably to the body of the soil. It takes 134 cubic yards of earth to cover an acre one inch thick. This quantity of clay added to a sand would add 12 per cent. to the cultivated depth of the soil, if the plough went eight inches deep. This might be considered a heavy and expensive dressing. Its effect in changing the character of the sand would be more noticeable than the same bulk of sand in altering a tenacious clay.

In adding clay or marl or chalk to a soil there is one point that must be attended to. The substance applied must be exposed on the surface of the soil to weather before any attempt is made to incorporate it with the soil. In

a temperate climate the frost of winter will crumble the crude lumps of clay, &c. While in a hot climate, rain succeeding heat will be found equally effective towards the same end.

USAR LANDS.

Salt sterile land are common in India.

Usar lands occupy considerable tracts in the North-West Provinces of India and other parts of upper India. Salt lands are found elsewhere in hot countries throughout the globe. They are characteristically present in the Thásra táluka of Kaira and under the Nira canal in the Bombay Presidency. The sterility of these lands is due to an excess of soluble salts existing in the surface soil and often to no other defect. The soluble salts make themselves apparent as a white encrustation on and near the surface. This efflorescence is called *reh*, and consists usually of salts of sodium, common salt associated with sulphate and carbonate of soda. In the North-West Provinces, Dr. Leather found the principal salt nearly always sodium carbonate. In the Kaira district the principal salt was chloride with sulphate and carbonate also present. In some places nitrate of soda and nitrate of potash are encrusted with other salts on the surface ; but it is not usual to find any salt of much manurial value in characteristic *usar* tracts.

The manner in which *reh* is formed and the effect of the harmful salts on vegetation.

The salts are presumed to exist in quantity in a layer, more or less distant from the surface, and the upward capillary movement of water brings up these saline ingredients in solution. The capillary moisture is evaporated by the sun's rays, and the soluble salts are left as crystals at or near the surface. The percentage does not usually exceed 2 per cent. and is often much less. Dr. Leather describes a series of interesting pot culture experiments which he conducted. I take the following information from the report. Good garden soil known to contain no appreciable amount of any of the injurious salts was used. Definite amounts of each of the three harmful salts were added singly. Each was found to retard germination. The cereals were affected in this way by 0·7 per cent. of sodium carbonate or sulphate and by 0·4 per cent. of chloride. The germination of leguminosæ was affected by smaller amounts. In the after-growth 0·2 per cent. of carbonate did harm and 0·4 per cent. was quite fatal. 0·2 per cent. of chloride did no harm. Sodium sulphate proved less harmful than carbonate or chloride, and perfect growth was maintained with 0·5 per cent. present in the soil. During after-growth as well as in germination leguminosæ were more severely affected than cereals.

A general description of usar lands.

The surface of *usar* land is an impervious layer holding water with great obstinacy when wet with rain. The presence of salt gives it in the fair season a light distinctive colour. The encrustation and the consequent barrenness which the presence of salt causes are not usually uniform over a large area.

Usar land has a patchy appearance. Elevated land is not so seriously injured as low-lying. The explanation is that during the rains the salt may be washed from the knolls to the hollows, and moreover, on an uneven surface evaporation of capillary moisture is more persistent from the low-lying places than from those more elevated. *Reh* encrustation is formed in the greatest degree in those situations where there is the greatest degree of evaporation. The worst *usar* land is undoubtedly situated in declivities where the natural drainage is obstructed, and where an excessive rainfall would probably produce a swamp.

Methods adopted in India to improve usar land.

Although various attempts have been made to secure a fair return by cultivation from *usar* land, it can not be said that that has yet been accomplished. Fair progress has, however, been made. The worst description of *usar* land is not completely destitute of vegetation. The vegetation is more or less patchy—*khar usar*—a coarse benty grass grows. It provides fair forage which cattle will eat. Dub grass will grow where there is less salt. The enclosure of *usar* lands prevents village cattle grazing the natural herbage, and, moreover, tends to cause the establishment of vegetation where it did not previously exist. Cattle, if admitted for grazing during the rains, puddle the soil into plastic mud, and the natural vegetation does not get a fair chance of being established. If the surface is even sparingly covered with any kind of vegetation evaporation occurs through the plants instead of directly through the soil; therefore the soluble salts, not accepted by the plants as a requisite food, are distributed through the body of the soil and are less hurtful, because not accumulated in the upper layer. The cultivation of salt-feeding plants removes a perceptible percentage of those salts which in excess are poisonous to ordinary cultivated crops. Many kinds of trees have been tried, and some have established themselves but a *murum* or impenetrable layer impregnated with salt is found often at a distance more or less distant from the surface, and usually trees become unthrifty or die as soon as their roots strike the impervious layer. The trees which have succeeded best are *bábhul* (Acacia Arabica) or *kinkar* (Acacia jacquemontii), *kikar* (Acacia leucophlœa), rain tree (Pithecolobium saman), sissoo (Dalbergia sissoo), white siris (Albizzia lebbek), Australian salt bush, &c. Trees have thriven for 10 or 15 years and then have suddenly died, presumably owing to the roots reaching the subsoil salt layer. The most successful manner of establishing trees is to dig holes at least three feet deep and wide, and replace the excavated soil by earth not impregnated with salt. This prepared seed bed should be raised about nine inches above the level of the surrounding surface. Canal silt filled into the excavated pits and raised as described, has proved most successful.

Free planting on usar land.

Effect of drainage, tillage and manure.

Reh salt can be removed if drainage can be secured, and if the surface soil is kept freely open by tillage and by admixture with large quantities of organic manure. Rain falling on an open friable surface washes the salt out of it, and if there is a free escape for the water into the subsoil, the salt may in

this manner be permanently removed, provided the land is kept continuously under arable cultivation afterwards. Although the improvement may be a permanent one the initial cost will prove ordinarily, almost if not quite, prohibitive.

Reh encrusted lands lying at a level which can be commanded by canal water may be washed free of salt by flooding, and subsequently allowing the water to escape carrying with it in solution the efflorescent salt. The practical difficulty is that *usar* tracts are so level that a free outlet for flood water is often difficult to obtain. Salt land has been made cultivable by embanking small areas and letting in canal water to deposit its silt. Land has been warped to the depth of three feet in the North-West Provinces in this manner, and although the expense was considerable, the enhanced value of the land for the time being (and probably for all time), gives an equivalent return for the outlay. Land treated in this manner 10 years ago has since continued to produce good crops.

Flooding, embanking and warping.

The progress of *reh* is a serious agricultural danger in districts where irrigation canals are led. We may with advantage provide a rainless tract with water for irregation, but it is of equal importance to provide an artificial outlet for the water when it has done its work. If land adjacent to a canal becomes surcharged with subsoil water, salt will in all probability become encrusted, owing to the persistent evaporation at the surface and the upward capillary movement of water thereby excited.

Reh near canals.

In Egypt an extensive and elaborate system of canal irrigation has of late years been engineered, and at present the most pressing agricultural question appears to be how to get rid of an excessive amount of subsoil water and those alkaline salts which the water brings to the surface. In the marsh lands of Egypt salt has been successfully washed out of the land by embanking small areas, the bunds being formed by earth excavated from ditches or drains dug along the lines of embankment. The embanked land is flooded. The water soaks into the soil and dissolves the salts formed at the surface, as well as in the body of the soil. It drains to the open ditches, if the bunded area is not large and escapes carrying the alkaline salts in solution if the ditches have a proper outlet. Surface drainage effected by "lands and furrows" has proved useful in India. In the rains the surface salts are washed into the furrows, the water escapes by an open ditch or leading drain at the lowest part of the area.

Reh in Egypt removed by drainage.

In India gypsum and farm-yard manure applied to the worst description of *usar* land, has had a most beneficial effect especially when associated with deep tillage and drainage. Land reclaimed in this manner has produced good crops but the expense is high. Dr. Leather has been able to throw a new light on the action of gypsum. He points out that when *usar* soil is shaken

Applications of gypsum and farm-yard manure with deep tillage and drainage useful remedies for *reh*.

up with water to dissolve the alkaline salts present, it is a very slow process to filter off the water extract. An extract from ordinary soils can be quickly filtered. The addition in small quantity of gypsum or calcium chloride to the muddy liquid of *usar* soil has the effect of curdling the soil particles, so that the water extract passes readily through an ordinary filter. Dr. Leather believes, that in practice the extreme impermiability of *usar* land may be altered by the application of gypsum (got in large quantities in the Himalayas) owing to its curdling action on soil particles and, moreover, the pernicious sodium carbonate may be converted into the less harmful sodium sulphate.

THE EFFECT ON SOIL AND CLIMATE BY PLANTING TREES AND GROWING GRASS.

Forest growth generally improves the surface soil and also improving the climate.

The chief chemical improvement of the surface soil caused by the establishment of a forest growth is brought about, because trees send their roots far in search of food and moisture, and by their natural decay or by the annual fall of their leaves add year by year to the fertility of the upper layer mostly at the expense of the subsoil. In reserved forest tracts, a sward of more or less value as grazing becomes established, and prevents that waste of soil material by surface washing, which would inevitably occur in any bare exposed surface during the monsoon rainfall. Any soil carrying a forest growth of some age is usually rich brown in colour, friable and moist, the decaying vegetable matter which it contains giving it these qualities. Tree-planting has an influence not only on improving the soil, but also on improving the climate. Where forests have been cut down or destroyed the rainfall has diminished. The converse would also be true. Plant trees and the rainfall will increase.

Forests not easily established in India.

It is much easier to show the advantage of forest growth than to establish a thriving plantation. Seed sown will germinate, and the seedlings will survive as long as there is moisture in the soil; but in India, the arid hill-sides and blistering heat of the hot weather furnish long odds against the survival of seedlings. A year of scant rainfall may come, when trees fairly established may perish. A solitary tree standing by itself is more likely to succumb than one in a clump; because even a small plantation shades the ground, conserves the moisture and prevents the soil cracking as it would do if more exposed.

It is easy to grow trees in some kinds of soils.–The advantages of hedgerow trees in agricultural districts and the disadvantages.

Trees can be more easily grown along hedgerows in soils which do not crack than in those which fissure freely. The difficulty of growing hedge-row trees is in some districts the reason why cowdung is so extensively used as fuel. In open districts, trees whilst young must be protected from goats, also from buffaloes. The latter destroy young trees by rubbing up against them.

Hedgerow trees are valuable as yielding fruit and fuel, but they are valuable in other ways. In stock districts as affording shade during the heat of the day they are invaluable. Moreover, the natural shelter which they provide, prevents the prevailing winds or storms from sweeping across a district with the same destructive force as would be the case in an open treeless plain. Shade trees are not without their disadvantages. They rob the surrounding soil of moisture and of plant food to the disadvantage of a cultivated crop. Their shade interferes with a growing crop for a considerable distance. It is a common saying that nothing will grow under *bábhul.* Strictly that is not true; for some of the best hay *kurans* in the Presidency are completely shaded by *bábhul.* Its effect upon the cultivated cereals is distinctly disadvantageous, and is probably more so than the effect of any other tree. Mangoes are the least objectionable in this respect that I have observed. A beech wood in England is seen often with hardly a trace of any undergrowth. It is believed that the drippings from some trees in wet weather are poisonous to the plants that attempt to grow underneath them. Although no cultivated crop grows vigorously under a *bábhul,*still if the tree is cut down the spot will be marked by an extra growth of cultivated vegetation for years afterwards. Experiments at the Nágpur farm have proved that the shade of trees is not to any extent harmful, that if a trench is cut sufficiently deep to cut through the lateral roots, then the tree cannot rob the adjoining field of moisture and manure, this robbery and not the shade being the chief cause of harm.

Grass land: Causes of improvement and deterioration.

Laying down the land to "permanent pasture," or the non-cultivation of waste land, which is the Indian equivalent tends to improve the surface soil. Partial rest is given and if English experience is any guide, there is a gradual accumulation of nitrogen in the surface soil. In England it has been proved that in grass land which has been down many years, there is about double the quantity of nitrogen that there is in an ordinary arable field. Moreover, there is in all grass land a yearly addition to the mass of underground fibrous roots which not only add to the depth of the soil, but increase its friableness and make it more pervious to air and water. By the decay of so much vegetable matter there is an increased formation of humus. If hay is cut every year and no equivalent returned as manure, the soil and grass may deteriorate; but if pastured there is an annual improvement. It takes many years to obtain the rich close sward that would be termed good grass land. It is well known that such land has accumulated much fertility and would take years of arable cropping to exhaust it.

Natural herbage.

Land that is under arable cultivation in India is prone to become infested with *kunda* and other deep-rooted grass. If, however, allowed to lie waste for a term of years, both *kunda* and *hariáli* will give place to grasses indigenous or natural to the soil. And such waste land, if the soil is deep

and naturally of good description, will, when broken up for cultivation, bear cropping without manure for a number of years, and show no appreciable sign of exhaustion or even of impaired fertility. This in the writer's experience is generally the case, and is particularly so in the deep black soils of Surat and Broach.

MANURES.

RÁB.

In tracts of heavy rainfall where *nágli* (Eleusine coracana) and *vari* (Panicum miliaceum) are grown on the uplands and rice on the lowlands, *ráb* is practised. These crops are grown from transplanted seedlings. These seedlings are almost invariably raised in a nursery on which *ráb* material has been burnt. *Ráb* is not required for salt rice.

Ráb required only in districts of heavy rainfall.

The most favoured materials for *ráb* are cowdung and branch loppings from the *ain* (Terminalia tomentosa) tree. This brushwood and other brushwood considered inferior in quality to *ain*, is cut when the branches are tender and the leaves in full vigour and growth, and some time before it is required. Other accessories are coarse dried grass, leaves, straw, &c. But it is only in circumstances of necessity that the cultivator attempts to burn *ráb* material from which cowdung or branch loppings are absent.

Ráb material.

The nursery seed bed is often on the same area, year after year, and favoured situations in certain villages are considered by the cultivators specially valuable for the purpose. It is imperative that the seed bed be at the highest level of the field, or on ground not liable to be swept by flood-water. Seedlings whilst young and tender would be damaged by heavy surface drainage.

The seed bed.

The cultivators are busy collecting *ráb* material from December on to March. The combustible materials are arranged in layers with the greatest precision and care. The main layer whether it is cowdung or branch loppings is laid next to the smooth surface of the seed bed, with successive layers of dried grass, leaves, trampled *nágli* straw or rice husk, with an upper layer of finely pounded earth or mixed earth and pit manure. Sometimes the seed bed is dug with a light hand pick, and the lumps broken fine before the *ráb* material is laid upon it. The amount of accessories required for cowdung *ráb* is about half that required for brushwood. The object of having a layer of rice husk or bruised straw between the pounded earth and the lower layers, is to prevent the finely sifted soil running through the interstices of the lower layers; and for a like reason the upper earth layer is not put on until all the other material is arranged ready for ignition.

Collection of *ráb* material and preparation of the seed bed.

The upper layer of earth prevents the too hasty burning of the *ráb* and, moreover, keeps the fine ashes from being blown away by heavy winds. The

Burning the *ráb* material.

burning is generally done during March, April or May. It is important to burn *ráb* in the early morning, and when there is an abundant deposition of dew. The sifted earth moistened by the deposited dew remains as an upper layer, and the burning is completed by eight o'clock in the morning after which hour, the heat of the sun would dispell the dew moisture. If there is no dew, water is sprinkled over the *ráb* material before the earth layer is added. The object is to smother-burn the whole mass so that the soil of the seed bed gets the full effect of the heat generated. Fires are started on the lee side, and after burning nothing should remain of the *ráb* material but a fine ash. The action of the fire is somewhat analogous to that in clay-burning or paring and burning in England. In each case, some of the results are similar ; namely, a fine state of tilth, a good seed bed, the eradication of weeds and the destruction of insect pests and their larvæ.

The effects on the soil and the seedlings produced by burning *ráb*.

Although the manurial effect of *ráb* is appreciable, the other effects are much more so. There is no doubt that if the *ráb* material used is of high manurial value, the seedlings will be all the better, and this is true irrespective of the fact that burning occasions a loss of organic matter and nitrogen, each of which we are accustomed to think highly valuable. A well *rábed* seed bed is capable of producing healthy vigorous seedlings which are ready for transplantation early in the rains. The transplanted crop thus gets the full benefit of the monsoon, and this is important because rain usually fails too soon for a late transplanted crop. If the seedlings are strong and well grown fewer are required to transplant a given area than if they are weak.

Sowing the seed and transplanting the seedlings.

If the surface of a seed bed is lightly dug before the *ráb* material is laid thereon about one inch of the surface soil is burnt to a brick red dust. The seed is sown in the burnt soil and ashes of *ráb*, sometimes when there is evident appearance of immediate monsoon rain, more commonly after the first showers have fallen. The land is once shallow-ploughed to cover the seed and carefully levelled. It takes about 25 to 35 days from the time the seed germinates until the seedlings are fit to transplant. Meantime the area to be transplanted is prepared for transplantation usually by three to five ploughings. Every seedling is removed from the seed bed, and its area having been once ploughed is also transplanted. The yield of grain therefrom is usually bountiful, and is preferred as seed for the crop of the following year.

Mr. Ozanne tested the weight of *ráb* material used by good cultivators and the following figures are taken from his note :—

Cowdung *ráb*—Area of seed bed ½ *guntha* ($\frac{1}{80}$th acre).

The actual weight of *ráb* material required.

			lbs,
1st	layer	Cowdung	785
2nd	do.	Coarse grass	128
3rd	do.	*Nágli* straw	44
4th	do.	Mixed sifted earth	180
		and pit manure	135

The cowdung as usual was broken into small fragments and spread as a close layer over the whole surface of the seed bed. $6\frac{1}{3}$lbs. seed sown on the above seed bed produced seedlings sufficient to transplant, $3\frac{7}{16}$ *gunthas.*

Ain rāb—Area of seed bed $\frac{1}{2}$ *guntha* ($\frac{1}{80}$th acre).

			lbs.
1st	layer	*Ain* loppings	680
2nd	do.	Coarse grass	277
3rd	do.	*Nágli* straw	88
4th	do.	Sifted earth	360
		and pit manure mixed	270

$6\frac{1}{3}$lbs. seed broadcasted on above seed bed gave seedlings sufficient to transplant $2\frac{7}{8}$ *gunthas.*

Much of the *ráb* material is obtained outside the cultivated area and ordinarily in forest reserves. At one time the hill or *varkas* lands were reserved by hereditary custom to cultivators of rice to enable them to procure a supply of *ráb* material, but as the population became congested, these *varkas* lands also were brought under cultivation, and as a matter of fact, the cultivation now of these uplands also demands a supply of *ráb* material. In cultivating such land the practice is to grow *nágli* from seedlings raised in a *rábed* seed bed, then *vari* similarly grown. *Kodra* and other coarse grains may follow *unrábed*, but after four or five years' cropping even on the best hill land, the soil is allowed to remain waste or fallow sometimes for five years, often for ten. During this period scrub brush-wood and grass spring up, and when it is again intended to crop such land this growth is burned as a preliminary to successful cultivation ; and this is undoubtedly a wasteful process. But as regards the legitimate *rábing* of seed beds, it may be taken as proved that it is essential to the successful cultivation of rice, *nágli* and *vari* in all districts of the Bombay Presidency where the rainfall exceeds 60 or 70 inches.

Ráb is essential for rice, *nágli* and *vari* in districts of heavy rainfall and branch wood from forests is essential.

MANURE SUPPLIES IN INDIA.

Dr. Voelcker in his "Improvement of Indian Agriculture" says :—"Water and manure together represent in brief the *rayat's* chief wants. In some respects the latter is the more important requirement."

Waste of manure.

Cowdung is probably the most important available manure in India. If the dung and urine of domesticated animals were preserved with ordinary care and used solely as manure, it is probable that the fertility of the area under cultivation would be maintained. Under existing conditions the urine, which weight for weight is as valuable a fertilizer as dung, is in most districts

entirely wasted. Its economic value as manure is either not understood or not fully appreciated. The dung is extensively burned as fuel, because in out-districts it is the cheapest fuel obtainable, and in towns its value as fuel is greater than its actual worth as manure. We may deplore this waste, but the practice will continue until a cheaper fuel is provided. At all large municipal centres, enormous numbers of work cattle, milch cows and buffaloes and horses are stabled. These animals are fed on much more concentrated food than cattle in the country, and, if the solid and liquid excreta were preserved as manure, it would be much richer than that produced in a *rayat's* homestead. The food consumed represents the agricultural produce of extensive agricultural districts; yet from towns practically no manure is returned to the cultivated land. The solid excreta are made into cakes, sun-dried and sold as fuel, whilst the urine drains away somehow. Village sanitation is making some progress, and to some extent the sweepings and nightsoil of towns are utilized as manure. Still there are in all centres of habitation extensive sources of manure supply, which are entirely or almost entirely neglected. This is owing partly to prejudices which will slowly be overcome. Where poudrette is used its value is well enough known, and its use as manure for irrigated crops is extending because it is so effective.

Bones exported largely.

Bones in most countries are regarded as valuable manure for almost all cultivated crops, and on account of their value as such are largely exported from India to Europe. The export during late years has generally averaged about 50,000 tons per annum. This, at first sight, would appear to be a drain upon the agricultural resources of the country, but I do not think that it need be deplored. Owing to the keen export demand the price of bones at the chief Indian ports has risen to a high pitch. The price is now (1900) so high that other materials (oil-cakes and other by-products), which as manure are more effective, can be obtained almost anywhere in India at a much cheaper rate. Everywhere the value of bones as manure is disregarded by the Indian *rayat* and not, I think, without just reason. Experiments have proved that for irrigated or ordinary dry crops in India, bones, though crushed fine, if otherwise untreated, are extremely slow in their action. For certain irrigated crops, it has been experimentally shown that the action of bones dissolved with sulphuric acid has been quick and powerful, but the cost of imported acid makes the price of dissolved bones almost prohibitive. The case might possibly be different if the manufacture of sulphuric acid was an extensive native enterprise.

Oil-cakes used as manure.

In irrigated garden lands various oil-cakes are extensively used as manure, and some of these by-products are in such request that the price has largely increased. This is notably the case as regards castor cake and *karanj* cake

(got from the seeds of Pongamia glabra). These cakes owing to their value as manure for sugar-cane and other irrigated crops are worth weight for weight more than certain edible cakes, which are much richer in the important elements of fertility, *viz.*, in nitrogen, in phosphoric acid, and in potash. The inference is that these edible cakes can, at present market rates, be more economically used as manure, than the manure cakes which are now so generally employed.

Indian manure supplies which are not fully exploited.

We have proved at Poona that safflower cake, niger-seed and ground-nut cake, cotton seed cake and cotton seed are in equivalent applications more effective and economical manures for sugar-cane than the ordinary manure cakes. I see no objection to using these feeding stuffs directly as manure in India, because if not so used they are either exported or fed to milch and other cattle in towns or elsewhere. If so fed, little, if any, return is made to the land, because the solid excrement is burnt as fuel and the urine is lost entirely. There are a few other sources of manure supply in India. Crude nitre is a local product in many districts which as manure is more or less used, and with good effect especially on such crops as tobacco, brinjalls, potatoes, and other members of the solanaceæ. All the members of this natural order are known to be much benefited by a manure which contains potash as well as nitrogen. Purified nitre is, however, far too valuable for the manufacture of gunpowder to be used as manure. Dried fish from about Thána and other parts of the Bombay Coast is extensively employed for sugar-cane and for many other garden crops. It is also used for *nágli* (Eleusine coracana) in the uplands of the Konkan.

The *rayat* is looking about him for new sources of manure supply.

There are indications that the *rayat* is looking about him for new sources of manure supply, and that good cultivators conserve the excrement of their farm animals, and are anxious to supplement the supply by preserving night-soil, ashes, and household refuse. This is certainly the case in parts of the Poona District, also in Surat, where owing to the extension of the cultivation of irrigated crops under wells manure is in special demand. There are sources of manure supply in India which have yet to be exploited, for instance, refuse from manufactories, tanneries, slaughter-houses and such like. It is known also that mineral manures exist. At the same time the manurial resources of India are small in comparison with such countries as import manure or feeding stuffs largely, or have indigenous supplies of mineral manures. It is not at all likely that it will ever pay to import concentrated manures into India, and the wants of the country become all the more serious, because the present system of cultivation in many districts is a huge drain upon the agricultural capabilities of the soil.

Manures are specially necessary for irrigated crops.

Dry crop lands are usually very sparingly manured.

In the black soil districts of Khándesh, Broach and Surat, there are many fields and in particular the more outlying fields of villages which are never manured, and others which are lightly dressed at very long intervals. The natural

fertility of deep black soils is undoubtedly great, yet I am impelled to believe, that the day will come when an adequate return must be made to these soils to compensate for what crops remove, or else their producing powers will be at a very low figure. It may be accepted as certain that under existing conditions a great deal of the land under cultivation in the Bombay Presidency, and especially in the Deccan, is undergoing a slow system of exhaustion. Yet as a contrast it is satisfactory to know, that with facilities for irrigation and under the management of most skilful cultivators, a faultless system of cultivation is occasionally met with. In Gujarát good farming is more common than elsewhere, but even in the Deccan one strikes a village now and again a veritable green spot in the surrounding desert, where cultivators of good agricultural caste make the very utmost of the few acres they cultivate. Their plan of cropping shows an intimate knowledge of rotation. Their management shows that every square foot of waste land is grudged, and every scrap of organic material of value as manure is stored with the most jealous care. It is probable that cultivation of this kind practised here and there now will by-and-by extend by the force of good example. Of late years, a great impetus has been given to the cultivation of irrigated crops through the manufacture of poudrette by Municipal Corporations. The poudrette is sold readily to cultivators. Yet it seems an anomalous fact that poudrette should be valued so highly, whilst cowdung for fuel is carted to municipal centres where poudrette is manufactured, and this too, from those surrounding districts, where the poudrette is actually used as manure. This occurs where poudrette is sold approximately at Rs. 5 per ton. The inference is that the cultivator makes money by selling his cowdung as fuel, and replacing it by poudrette costing the above named price.

Irrigated lands are much more liberally cultivated.

The necessity of conserving manure from all available sources.

I have indicated briefly that there are, in India, internal losses of manurial matters which might be avoided. Moreover, the agricultural produce is largely exported, and the export of grain, of oil-seeds and of numerous other soil products saps the agricultural capabilities of our fields. The loss in one respect is a national gain, because a full equivalent in currency or otherwise is got; but the loss is all the same an agricultural one, and should force the conviction that it behoves the agriculturist to hoard all that there is of manurial value in the country, and use it in a legitimate manner, and in that way in which nature intends that it should be used. If the fertility of the land is to be upheld, the waste products of domestic life, the refuse of slaughter-houses and tanneries, the by-products of many manufacturing industries and the excreta of animals must be better conserved, and more generously employed as manure than is the case at present. Although the indigenous manure supply is not likely to be augmented by import, it is likely that mineral phosphates which are known to exist in India, and those potash and nitrogenous salts which are

found incrusted at or near the surface of old village sites and elsewhere, will in time be used as manure to a greater extent than they are now. The system of green manuring will likewise probably extend, and the practice of growing leguminous crops subordinate to cereals will always be popular, because this practice has helped a very great deal in arresting the exhaustion of the soils of India. The extension of irrigation and other works calculated to avert famine, the provision of cheap fuel other than cowdung, the increase of the fodder supply by the establishment of fodder reserves and otherwise, and the control of cattle disease will each tend to help the cultivator to store a larger quantity of farm-yard manure than he can at present, and make him less dependent upon outside supply.

The important elements of plant food which manure supplies.

There are fifteen essential elements of plant food. Of these carbon is derived from the atmosphere ; nitrogen partly from the air and partly from the soil. Hydrogen and oxygen are derived mainly from the soil-water, which in ordinary seasons is sufficient not only for this purpose, but also to replace the water which after circulation through the plant is lost by evaporation. All the other elements are entirely derived from the soil, and are taken up in solution through the roots of plants. To satisfy the requirements of vegetation each necessary plant ingredient must be present in the soil in sufficient quantity and in a soluble form. The cultivation and removal of crops necessarily lessens the normal supply of these essential elements in the soil, and manures become necessary. Manure may be regarded as plant food incorporated with the soil in order to supplement the natural stores therein. Experience has shown that manures need not contain all the essential elements of plant food. Generally speaking, exhaustion is due to the failure of one or more plant constituents. It is conceded that the important elements of fertility are nitrogen, phosphoric acid, potash and lime; and it is the proportion in which these exist in a manure (particularly the three first) that gives it a certain commercial value. Sometimes an element of minor importance is found wanting when its addition to the soil becomes compulsory, otherwise sterility will follow.

Manures exercise other effects besides providing plant food.

Manures exert other effects. They act by promoting the decomposition of rock fragments and minerals, setting free certain substances, and facilitating their absorption by plants. Lime as has already been noticed not only provides plant food, but acts upon the organic and inorganic constituents of the soil. Common salt and nitrate of soda exercise themselves in a somewhat similar manner. The addition of manure often causes a physical improvement. This is specially the case with farm-yard manure.

General manures.

A *general* manure contains all the necessary plant constituents, or at the least those constituents which, if added to a soil, will ensure continued fer-

Special manures. tility. *Special* manures on the other hand only contain one or two essential elements of nutrition, and are not of themselves sufficient to keep up permanent fertility. In fact, the inordinate use of special manures tends to accelerate exhaustion by causing the production of large crops, at the expense of those soluble substances which the soil contains, but which are not given in the special manure. It is a common practice for an out-going tenant in England to use, for a year or two before the termination of his tenancy, those special manures which an expert farmer knows will exert a stimulating effect upon the mineral matter of the soil, and help him to recoup himself for previous outlays in manures of a more lasting character.

Farm-yard manure is the best type of a general manure. It is a lasting manure, that is, its effect extends far beyond the year in which it is applied. Its liberal application causes a gradual accumulation of organic nitrogen in the soil which becomes slowly available, and in this respect is a contrast to a special manure like nitrate of soda which is either used at once by the plant or lost in the soil drainage.

Soils undergo changes under the art of husbandry. Good husbandry will tend to increase the natural productiveness of a soil. The manurial condition of any soil is maintained and probably improved by attention to the following points :—

Good husbandry.

(*a*) An equivalent return in the form of manure for what is removed by crops or otherwise.

(*b*) Thorough tillage.

(*c*) Systematic rotation and the free cultivation of leguminous crops in rotation with cereals.

Natural fertility.

The advisability of directing due attention to each of the above has already been alluded to. But it is as well to repeat here, that a senseless disregard of one or all of the above conditions is directly opposed to good farming. Some soils which are naturally deep and good can, by proper tillage, be made to provide, from their own resources, a sufficient supply of all the elements of nutrition to grow a certain minimum crop for all time. This is termed *natural fertility*. It would be poor economy to draw annually on the

Acquired fertility.

natural fertility of a soil although that course is too commonly pursued. Advanced cultivators know the advantage of added manure. Thereby a soil gains *acquired fertility*. Some poor thin soils have little or no natural fertility, and on such the owner is forced to use manure to nourish his crop, otherwise exhaustion in a year or two will occur. On the other hand the natural fertility of some soils is considerable. At Rothamsted, the greatest experimental station in England, probably in the world, a clay loam field resting on a substratum of yellow clay has been

devoted to the continuous growth of wheat for the last fifty-six years. The plan of this series of experiments is to compare the returns of produce from unmanured plots with those manured annually with (*a*) farm-yard manure, (*b*) with a variety of chemical manures. I tabulate below certain figures which show that there is a wide margin in favour of the manured plots. This would naturally be expected. The bearing of these tests is most instructive, because it is proved that certain descriptions of soils, under proper management, have a certain minimum degree of permanent fertility. A record of the Rothamsted experiments shows the astounding fact that fifty-six unmanured crops of wheat grown in as many years have not exhausted ordinary wheat land. The secret of this success is due to the scrupulous care with which each tillage operation has been conducted, to a total absence of weeds, to the thorough aeration and pulverization of the soil, and to the proper distribution of the seed in a favourable seed bed, in a word to perfect cultivation minus the use of manure.

The Rothamsted experiments with continuous wheat.

Although wheat has been grown unmanured at Rothamsted since 1844, in the subjoined tables the figures relate to results obtained during 41 years, 1852-1892. That period is selected because there was no variation throughout in the treatment of the various experimental plots. Comparisons may therefore be safely made between the results from the unmanured plot and those manured in a variety of ways.

Unmanured Plot—Wheat.

Period.	Grain in bushels per acre.	Straw in cwt. per acre.	Weight of grain per bushel.
			lbs.
20 Years, 1852-1871	$14\frac{1}{2}$	13	$57\frac{5}{8}$
20 Years, 1872-1891	$11\frac{1}{2}$	$8\frac{3}{4}$	$58\frac{3}{4}$
1892	$9\frac{3}{8}$	$7\frac{1}{2}$	$59\frac{1}{2}$

Continuous wheat manured annually, per acre, with 200 lbs. sulphate of potash, 100 lbs. sulphate of soda, 100 lbs. sulphate of magnesia and 392 lbs. superphosphate.

Period.	Grain in bushels per acre.	Straw in cwt. per acre.	Weight of grain per bushel.
			lbs.
20 Years, 1852-1871...	17	15	$58\frac{7}{8}$
20 Years, 1872-1891...	$12\frac{7}{8}$	$9\frac{3}{4}$	59
1892	$10\frac{3}{8}$	$8\frac{1}{8}$	$60\frac{3}{8}$

Continuous wheat manured annually, per acre, with 275 lbs. nitrate of soda.

Period.	Grain in bushels per acre.	Straw in cwt. per acre.	Weight of grain per bushel.
			lbs.
20 Years, 1852-1871...	26	28¼	56⅝
20 Years, 1872-1891...	19⅜	18½	56⅝
1892	10¾	11⅜	55¾

Continuous wheat manured annually, per acre, with 200 lbs. sulphate of potash, 100 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, 392 lbs. superphosphate, and 275 lbs. nitrate of soda.

Period.	Grain in bushels per acre.	Straw in cwt. per acre.	Weight of grain per bushel.
			lbs.
20 Years, 1852-1871...	36⅞	41½	58⅜
20 Years, 1872-1891...	34	37¾	59⅝
1892	25¼	23⅝	60½

Continuous wheat manured annually with farm-yard manure, 14 tons per acre.

Period.	Grain in bushels per acre.	Straw in cwt. per acre.	Weight of grain per bushel.
			lbs.
20 Years, 1852-1871...	35⅞	33⅞	60
20 Years, 1872-1891...	33½	31⅜	60¾
1892	33⅜	30¼	61¼

The lessons to be learned from the manure experiments with continuous wheat at Rothamsted.

The lessons to be learned from the figures of the preceding 5 tables, are as various as they are important. The results of the unmanured plot show that the yield is slowly declining. A comparison year by year also shows that the yield of grain and straw, particularly of the former, has been considerably higher in years with dry summers than in wet seasons, the latter

being unfavourable for heavy wheat crops. There is no doubt that the annual yield of grain and straw was increased during the earlier years of the experiments by residues left in the soil by former vegetation; but it may be concluded that this source of plant food has been exhausted many years since, and that the crops now grown owe their sustenance to the direct preparation of plant food from the soil and subsoil, and to the small quantity of nitrogen brought to the soil in the rainfall. The greater portion of each crop consists of organic matter obtained chiefly from the carbonic acid of the atmosphere. Moreover, a crop yielding 9 or 10 bushels of grain and 7 or 8 cwt. of straw per acre, does not require a large amount of potash, phosphoric acid and nitrogen to feed on, and the results at Rothamsted prove that a good deep wheat soil has sufficient natural fertility to produce middling crops of wheat for a very long time. But the annual outturn must of necessity gradually diminish. A heavy and expensive dressing of minerals alone has not increased the outturn over that of the unmanured plot to any appreciable extent. The soil of the experimental area is a deep clay loam, probably naturally rich in phosphates, potash and those other mineral elements which wheat requires. Consequently, the annual application of minerals alone has either increased a supply which is already ample, or the mineral manures applied have been washed away in the drainage. This has occurred because in the absence of an adequate supply of nitrogen, no crop can appropriate, except to a very small extent, other elements of plant food. The results from nitrate of soda alone are specially instructive. During the earlier years of the experiments and upto a comparatively recent date, the effect of a liberal application annually of nitrate of soda resulted in comparatively good crops. The manure exercised its well-known stimulating effect on the soil which was naturally rich in other elements of nutrition. But the Rothamsted soil could only bear this exhaustive drain on its mineral wealth upto a certain point, and the application of nitrate of soda during the latter year shows that it is now quite ineffective, because the soil is deficient in other elements of fertility. Nitrogen in the form of nitrate has proved more effective than nitrogen in the form of ammonia salts. But the ammonia salts do not appear to have stimulated the exhaustion of the soil to the same extent as nitrate of soda has done. A general manure applied in liberal quantity annually, whether made up of artificially mixed chemical manures or as farm-yard manure, has maintained at a high standard the fertility of the Rothamsted wheat land. Although the general manure and the farm-yard manure each contained the same weight of phosphoric acid, potash and nitrogen, the results of the farm-yard manure plot are the best, and if the respective plots are similarly manured for another fifty years, the superiority of the farm-yard manure plot will probably become,

year by year, more marked. Because when dung is applied continuously, the accumulation of organic matter in the soil increases, so that in time the acquired fertility will have increased to the extent that the soil will not easily be exhausted for some time by subsequent crops grown without the assistance of manure.

Indirect value of manure.

The Rothamsted records which I have referred to prove conclusively the advantage of manure, but it is unnecessary to pause for a moment to teach that fact. The advantage is admitted by every man who farms—nay, more—the art of manuring is inseparably linked with profitable cultivation. Absence of plant food not only induces a poor crop but favours a predisposition to disease and a likelihood of loss from crop pests.

Effect of the season.

Season has often a great influence on the returns per acre. However well a soil may be stocked with manure, the character of the season regulates the outturn. In India we know pretty well the effect of a deficient rainfall. A superabundance of rain is as often harmful, particularly in the early stages of the monsoon crops. Several days' rain without intermission swamps the soil, washes the available supply of nutriment beyond the reach of the roots of young plants, excludes the air from the soil, and causes a yellow sickly appearance, from which the plant rarely recovers. To resow the crop is often the wisest course. A similar unthrifty appearance is observable in more temperate climates—often in winter sown crops. During a cold backward spring, cereals—especially wheat grown in well manured land—are often affected in this manner, and are much benefited by the application at the time of nitrate of soda which supplies nitrogen in an immediately available condition. It would seem almost inexplicable that nitrate of soda should benefit a crop grown on soil already rich in nitrogen. The explanation is that nitrification cannot proceed except with a certain degree of warmth. Cold prevents the conversion of organic nitrogen into nitric acid and the plant is starved accordingly. The object of applying nitrate of soda under circumstances such as these is to carry the crop through a trying time.

The kinds of manure required for particular crops.

A good guide to the nature of manure, which would be most economically applied to a particular crop is afforded by a complete knowledge of the chemical composition of the mature plants of the crop in question. Pulses form an exception to this rule; because as we have already said, they leave the soil richer in nitrogen than before they were grown and at the same time they remove, per acre, a greater weight of that element than any other cultivated crop. To manure the soils on the scientific principles advocated above, may answer admirably well in those countries, where educated agriculturists can seek and obtain, when necessary, the expert opinion of agricultural chemists.

But in India, where our knowledge of the manurial requirements of the many agricultural crops grown is very meagre, broader principles must be practised until a more intimate knowledge is acquired. Moreover, it is very doubtful, supposing we had a perfect knowledge, whether it could be fully taken advantage of.

FARM-YARD MANURE.

Farm-yard manure is variable in composition for reasons given.

Farm-yard manure is essentially a product of the farm and may be regarded as one of the most important fertilizers known. It consists of the solid and liquid excreta of domesticated animals mixed with a varying amount of litter and other refuse. The solid portion consists of the undigested and indigestible food, while the liquid portion represents the waste from the animal body and is food which has been assimilated and again excreted owing to changes taking place in the tissues of the animal. The value of farm-yard manure depends not only upon the proportion in which its constituents are mixed, but also upon the age, condition and species of the animals producing it ; also upon the quality of the food, the kind and quality of the litter used, and upon the management of the manure heap, during and after accumulation. The manurial value of the solid and liquid excreta of domestic stock primarily depends upon the quality of the food consumed. If an animal is merely kept from starvation by poor unnutritious fodder, the waste of the body, voided as dung and urine, contains little of manurial value. On the other hand if highly concentrated food is given the manure is rich in nitrogen, potash and phosphates ; but this is more or less modified by the description of the animals fed. We know that young growing cattle assimilate those elements of food which are necessary to form muscle, bone, hide, horn and the various tissues of the body. We know that an in-calf cow takes from her food sufficient to develope her fœtus, that milk cattle in the secretion of milk utilize a good deal of the nutritious part of the food and that consequently the excreta from such animals is poorer than that from full grown oxen which are not worked or from barren dry cows.

The relation which exists between the food given to farm animals and the manure produced by them.

The solid food of domesticated animals consists of albuminoids, carbonaceous substances known as heat givers, an indigestible substance called crude cellulose and mineral substances. The crude fibre and heat givers merely consist of carbon, hydrogen and oxygen. The crude fibre and undigested heat givers existing in the solid excreta decay as the manure ferments and a carbonaceous substance is formed. This makes up a considerable portion of well rotted farm-yard manure, and when applied

to a soil adds organic matter which, of course, is valuable. It is the proportion of albuminoid matter and ash constituents in food which gives the animal excreta a certain manurial value. Gluten existing in the grain of wheat to the extent of 13 per cent. is an albuminoid almost analogous to legumin—the flesh forming principle—which exists to the extent of 17 to 28 per cent. in the seed of all pulses. There is a still higher percentage of albuminoids in the residue left when oil has been expressed from oil-seeds. Therefore oil-cake fed to cattle has a higher manurial value than gram, beans, &c., and a still higher value than the cereals. Similar differences might be shown as regards fodders.

The storage of farm-yard manure.

Farm-yard manure has no constant composition. It must vary with the kind of food consumed, and we have already seen other conditions influence its quality. When food passes through the animal body a good deal of the hydrogen and oxygen and much of the carbon are given off in respiration, but the excrements contain nearly all the nitrogen and ash constituents. Urine contains alkaline and complex nitrogenous compounds, the most simple of which are urea, uric and hippuric acids. These substances are easily fermentable, thereby becoming oxidized and forming nitrates and ammonia salts which are soluble in water, and are as manure the most valuable combinations of nitrogen; but the mere fact that urine changes so readily points to the necessity of preventing waste from this cause. The best plan in India of storing farm-yard manure during its accumulation is to have an underground pit with a masonry floor and sides. If this is situate near the stables and byres, the urine may be led into it by an open channel which should be flushed with water at least once every day. If this is not practicable, an open gutter behind the stalls will drain the urine into open cesspools from which it should be emptied twice a day and poured over the dung already collected in the manure pit. When the floors of byres are mud floors the urine soaks in and ferments. The pungent smell noticeable in badly-kept stables is due to the volatilization of free carbonate of ammonia from decomposing urine. Thereby in India there is an enormous loss. The urine is the most valuable part of the excrements, and I cannot too strongly urge the importance of preserving it in such a manner that during its fermentation, free ammonia is not lost and that the urine itself is not allowed to escape in drainage or any other way. Where fodder is scant and so valuable as it is in India, it would be folly to recommend the use of any description of straw as litter. But the fermentation of the manure can be far better regulated, if litter of some sort is used, such as leaves of trees, coarse grass, all waste fodder and everything of a vegetable or organic character that can be collected, then used as litter and afterwards carefully mixed with the solid and liquid excreta in the manure pit. The whole mass can be kept sufficiently moist to ensure proper

fermentation by the addition of water as it is required. If it is too wet, fermentation is retarded, if too dry a species of dry rot is induced which causes waste. The aim should be to get the manure to decay gradually into a friable moist condition. The whole will then have become oxidized. The nitrogen and other valuable manurial elements which originally existed in an organic form, will have become more or less soluble and therefore more or less available as plant food. These changes can be accelerated by turning the manure in the pit so soon as a considerable quantity has accumulated. In this way the oxygen of the air gets freer access, a greater degree of heat is generated, and if the whole is kept sufficiently moist, decay is hastened in the manner which is most desired. The temperature should never exceed 150° Fah.

The chemical changes which occur in farm-yard manure during storage.

There is little doubt that the nitrogenous compounds of urine, in the process of fermentation in the manure pit, evolve free carbonate of ammonia, but as the manure decays, ulmic, uric and other organic acids are formed, also gypsum, which fix free ammonia. In well rotted farm-yard manure the nitrogen exists chiefly as ammonia salts and only in traces as nitric acid or nitrate. It was at one time believed that so much oxygen was utilized in oxidizing the carbonaceous substances that there was very little available to convert ammonia into nitric acid ; but recent research has proved that if there is much organic matter present in a soil or in a manure, nitrates if they exist may be reduced to ammonia salts or even to organic compounds of nitrogen, the changes being brought about through the influence or action of bacteria. This reduction of nitrates may possibly account for the slow action of farm-yard manure when applied in heavy dressings in India to irrigated crops. In field experiments heavy dressings of farm-yard manure rich in nitrogen have given in India and elsewhere disappointing results as compared with more active manures, and the probable explanation is that the nitrogenous salts were reduced and therefore made useless for the time being as plant food. During fermentation farm-yard manure loses much in weight. The loss is chiefly due to the oxidation of the organic matter. Carbon dioxide is formed and escapes to the atmosphere. Pungent odours evolved from a manure pit indicate loss of valuable elements. The loss due to the volatilization of ammonia is usually, however, trivial. If, however, the manure is washed by rain-water and the drainage water is allowed to escape, then much that is valuable is carried away in solution. Well rotted dung is more liable to loss from this cause than fresh, because it contains a higher percentage of soluble salts, and this is a good reason, why farm-yard manure when sufficiently rotted should be applied to the land at once. There, if the soil has sufficient clay to give it a certain degree of consistence, nothing will be lost unless the field is washed by an excessive rainfall. A growing crop at any season is the best safeguard against loss by drainage.

Farm-yard manure exercises mechanical and chemical effects on soil material.

Farm-yard manure has a mechanical as well as a chemical effect upon the soil. It warms a soil. It helps to make land of a retentive character more open, and sandy soils more dense. It keeps a soil moist and renders by the evolution of carbon dioxide dormant soil constituents more soluble.

The manure from different animals should be mixed during storage.

The comparative value of the excreta of domestic animals is as follows :— (1) sheep, (2) horse, (3) pig, (4) ox. It is important that the dung from these animals should be mixed. Horse manure if stored by itself has a tendency to heat in an excessive degree and should therefore be mixed with the cooler manure from cattle.

Application.

Fifteen loads per acre may be considered an ordinary dressing of farm-yard manure ; 30 to 40 loads per acre a heavy one. It is important that dung be evenly spread and incorporated at once with the soil.

Analyses.

Cattle dung as preserved in India contains much less moisture than the farm-yard manure of Europe and weight for weight the former is much more valuable.

Dr. Voelcker gives the following comparative analyses :—

	Dung of lean Indian cattle, air-dried.	Farm-yard Manure, English.
Moisture	19·59	66·17
* Organic matter	59·26	28·24
† Mineral matter (ash)	21·15	5·59
* Containing Nitrogen	1·34	·65
Equal to Ammonia	1·62	·79
† Containing Sand	14·43	1·76
Oxide of Iron and Alumina	3·36	·42
Lime	1·04	1·35
Magnesia	·44	·15
Potash	1·16	·67
Soda	·34	·08
Phosphoric Acid	·47	·31

The loss of manurial elements occasioned by the burning of cowdung is pretty clearly indicated by comparing the foregoing with the subjoined analysis also by Dr. Voelcker :—

	Ash of Indian cattle dung.	100 parts of air-dried dung of lean Indian cattle containing approximately 20 parts Ash Composition as under.
Moisture	2·04	·89
* Organic matter	2·40	
Oxide of Iron and Alumina	9·26	1·85
Phosphoric Acid	1·37	·28
Lime	1·76	·35
† Alkalies and Magnesia	2·97	·59
Silicious matter	80·20	16·04
	100·00	20·00
* Containing Nitrogen	·17	·034
† Containing Potash	2·05	·68

Samples of well decayed farm-yard manure and of cattle dung from the Poona Farm were analysed by Dr. Leather with the following results :—

	Farm-yard manure being the dung of highly fed milk cattle preserved in a pit with litter & urine and kept moist by added water.	Farm-yard manure preserved in a pit similarly to sample I.	Cattle dung from cattle fed in ordinary way, collected fresh in pasture ground and stored in a heap, and sun-dried.	Cattle dung from cattle fed in ordinary way preserved in a pit without litter or urine and kept moist by rain-water.
	1	2	3	4
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture ...	36·19	28·69	10·73	43·96
† Organic matter	25·53	21·56	43·10	25·77
* Ash	38·28	49·75	46·17	30·27
† Containing Nitrogen ...	·853	·774	1·008	·887
† P_2O_5 ...	·149	·825	·290	·365
* Silicious matter	29·87	41·51	33·76	23·05

The above samples excepting No. 3 contained much more moisture than an average sample of cattle dung when ready for use as manure in India. All the samples were thoroughly decayed. The scientifically stored farm-yard manure does not show any superiority over the cattle dung in nitrogen or phosphoric acid, but it must be remembered that the admixture of considerable quantities of litter and of urine with the dung fills the manure pit quickly and a much larger quantity of farm-yard manure would be produced from a given number of cattle in a year than of cowdung manure.]

Analysis of urine.

Composition of the urine of Indian lean cattle and grain-fed cart bullocks (Dr. Voelcker) :—

	Lean cattle.	Cart bullocks.
Water and Volatile matters	91·77	90·62
*Non-volatile Organic matters	5·29	7·64
†Mineral matter (ash)	2·94	1·74
	100·00	100·00
*Total Nitrogen	·956	1·168
Equal to Ammonia	1·161	1·418
†Containing		
Silica	·004	·010
Lime	·161	·080
Magnesia...	·249	·570
Potash	1·528	·643
Soda	·050	·020
Phosphoric acid	·022	·022

Analyses of fresh dung, farm-yard manure and urine.

Mr. S. H. Collins gives the following analyses in his hand-book of "Agricultural Chemistry." Each analysis is the mean of several samples :—

	Fresh cattle dung, cultivator's cattle.	Fresh cattle dung, well-fed cattle.	Farm-yard manure decayed and ready for use.	Cattle urine.
Water	75	73·5	23	95
Organic matter	14·5	11	23	3·5
Nitrogen	·27	·35	·9	·56
Phosphoric acid	·18	·14	·17	·02
Potash	·30	·18	......	1·13
Lime	·28	·25	......	·12

POUDRETTE.

A practical and profitable method of utilizing human excrement as manure is specially important in India. In the light of up to date sanitary knowledge there is no doubt that with a properly organized water-closet system and regular house to house connections the sewage drainage of any city can be so purified that it can be used as a source of irrigation and of manure for crops without producing unsanitary effects. The purification is effected by several processes, the most effective of which is a septic tank and filter beds system. Other effective processes are known as "Dibden's filters" and the "Macerating Tank System." We have had each system in experimental operation in connection with sugar-cane experiments at Mánjri (Poona) and the results are fully reported in my annual report for 1899-1900. It is unnecessary to enter here into full detail. The purification is brought about through the influence of bacteria and in the space of 24 hours, the whole of the solid matter of the sewage disappears.

Sewage purification.

The organic matter is converted into soluble inorganic salts. The test of complete purification is the conversion of all the organic nitrogen into nitric acid. In the Poona experiments the purification was not quite complete, the nitrogen being converted mostly into nitrites. The effluent from the purified sewage was clear and the smell so faint that it was hardly noticeable. This effluent has been proved a most valuable and quick acting manure for sugar-cane and other crops, and at present I believe that it can be used as continuously as canal water for irrigation without causing unsanitary conditions of any kind. It is proposed to apply the system to the whole of Poona; and the Poona sewage scheme as engineered by Mr. J. C. Pottinger, Sanitary Engineer, Government of Bombay, is described in two addresses to the Municipality which he has recently published.

The chemical changes which occur during purification.

Pure sewage cannot long be used for irrigating and manuring one particular area because the land to which it is applied requires intervals of rest. If used continuously the pores of the soil get choked with slimy organic matter which obstructs aeration and in consequence an unhealthy condition of vegetation is produced.

Pure sewage cannot on the same land be continuously used.

In rural districts in England the earth closet system is practised. The same system is common in Ceylon. This consists in covering the solid and liquid excreta with earth. The urine is absorbed, the solid excreta deodorized. Earth, particularly good loam, has this power. The effect is due to humus and clay. In Poona and many towns in India, the deodorizing power and absorptive effect of earth or carbonized material is taken advantage of in the preparation of poudrette. The night-soil is collected and also the town sweepings and leaves, &c., and carted to a depôt outside the municipal limits. The sweepings are burnt or rather charred. The ashes

The earth closet system. The deodorizing power of good earth.

still containing a good deal of carbon are mixed with the night-soil. The ashes, if used in the right proportion, exercise a disinfecting power in deodorizing the whole mass. The resulting manure is a source of handsome revenue. A decided caste prejudice existed for years against its use, until its effect upon sugar-cane and garden crops was made perfectly clear to the cultivators.

The Poona methods of making poudrette.

The following is the method of manufacture of poudrette at Poona. A series of beds 18 feet long, 15 feet wide and 1 foot deep are floored with *murum*. A layer of ashes about 1 inch deep, is laid on this floor, and night-soil poured thereon to a depth of about 5 inches. The mass is immediately covered with another thin layer of ashes one inch deep; and thereafter allowed to stand 24 hours during the fair weather, and for three days during the rains. Wooden rakes are then used to mix the night-soil with the ashes. Another layer of ashes is now added, and the whole allowed to remain from three to eight days according to the state of the weather. It is then removed from the beds and dried on dry open ground. In the hot weather it is dry in five days and ready for sale and use. In the rains the whole process is conducted under cover and takes a longer time. When moist poudrette is heaped up sometimes, as with farm-yard manure, an excessive degree of heat is generated which causes loss of nitrogen. In the cantonments of Poona another method is adopted which is decidedly more sanitary. Pits of convenient length and width are dug, sometimes five feet deep. Into these pits the night-soil and dry pulverized earth are put in alternate layers and equal proportions. A capital manure results, but it is not ready for use for several months. It is not of course so concentrated a manure as poudrette made in the ordinary Poona way.

Poudrette valuable for certain crops.

Poudrette is recognized as an active and powerful manure for all irrigated crops in which a rapid and luxurient growth is desirable. It is very suitable for sugar-cane, lucerne, vegetables and all fodder crops. It is too forcing for grain crops and fruit trees. The plant is stimulated into active growth at the expense of fruit or grain. Poudrette is seldom applied except where irrigation is practised. It is worth in Poona as much as Rs. 3 per cart-load, but in seasons of scant rainfall, when a supply of irrigation water cannot be guaranteed, it falls in value to less than Re. 1 per load. Poudrette is applied at the rate of 15 loads per acre, upto as much as 80 loads per acre for sugar-cane.

Application per acre.

Composition of poudrette.

Dr. Leather's analyses show that Poona poudrette contains about 1 per cent. of nitrogen and generally a slightly higher percentage of phosphoric acid. The percentages of these ingredients vary with the percentage of moisture. If poudrette was generally manufactured throughout India at all populous centres, it would probably be the cheapest and best manure procurable.

SHEEP AND GOAT FOLDING.

Wandering flocks are used in the fair season for manuring arable lands.

This is a capital method of applying directly to the land the solid and liquid excreta of goats and sheep. It is practised at all seasons except during the monsoon. It is common to manure the land in this manner in Gujarát for tobacco as well as other crops. There are not many sheep owned locally; but at certain seasons professional shepherds bring large flocks from Káthiáwár. These are allowed to graze at random over the fields during the day; but the shepherds camp upon a particular field at night, and the owner of the field pays for the advantage which he gets. This payment is made in kind, 80 lbs. of *bájri* being allowed for the folding of 500 sheep per night. The shepherds also get small quantities of tobacco, along with other perquisites. It is a common practice for the owner of the field to disturb the flock several times, during the night. This he does because he knows that each time the flock is disturbed, almost every individual animal will urinate. The Gujarát cultivator is a shrewd individual and fully appreciates the manurial value of urine. In the hot weather large flocks are also to be found in several of the Deccan districts. No crop grows at this season on ordinary dry crop land and the sheep clear the fields of anything they can find to eat. At night the shepherds surround the flock and the land gets the benefit of the sheep droppings. This is a primitive method of sheep folding.

Systematic folding.

If folding is done systematically, wooden hurdles are an advantage though not a necessity. Hurdles ought to be fitted with stays or supports, so arranged that the hurdles can be set up to form a fence without being either driven in the ground or supported by stakes. This is necessary because the ground gets baked so hard at certain seasons that to drive stakes is impossible. The sheep should get a fresh fold every night so that hurdles that can be easily moved and expeditiously set up are necessary.

The extent of folding necessary and the particular value of the system.

A flock of 200 will sufficiently manure an acre of ground in 8 to 10 days. Sheep and goats void their solid excreta in such a form that it is evenly distributed over the surface in the process of folding. Moreover, the organic portion of sheep and goat dung, owing to the complete mastication of food, is in such a finely divided state, that the manure when mixed with the soil soon decays. It is richer in the elements of fertility, than the manure of any other kind of domestic stock. This, however will only hold good if the food ration is liberal. Usually the sheep in India manure the arable land at the expense of the common grazing. They are grazed during the day on waste land or wherever they can get sufficient food, and at night folded. The shepherd must remain with his flock to prevent attacks from wolves, &c., and some arrangement for his comfort should be made.

The Bhadgaon Farm system.

On the Bhadgaon Government Farm it was found quite practicable to fold a large flock of goats and sheep regularly over the arable land without hurdles. The older animals by keeping a few of their young ones in a moveable shepherd's house on wheels, lay quietly during the night, the shepherd with his dogs being close by to frighten wolves away which are rather common and destructive. The shepherd's house is easily moved by a pair of bullocks every third day. A little fodder should be given at night to the flock.

The soils most suitable.

All descriptions of soils, when the weather is dry, are improved by folding, but more especially light lands. The field folded should be clean. If the land is foul from deep rooted grasses, or any other weed, the soil gets consolidated. The manure encourages deep rooted weeds to send out new shoots, so that the pest gets thoroughly established. The plough should be worked close up to land folded, so that there is no waste of manure by unnecessary exposure. If ploughed in at once this is avoided. The flock should therefore be folded, along the length of the field and when a strip has been manured it can be ploughed at once.

Yards for sheep during the monsoon.

In the rains or when the land is wet, it would do more harm than good to fold sheep. A yard or enclosure is necessary for the flock at this season. The manure need not be lost. Littering the yard is out of the question. But a load or two of soil or ashes spread over the floor of the yard, two or three times a week and as often scraped together and carted to the general manure pit, will prevent loss.

Sheep and goat manure readily saleable.

The owners of sheep and goats generally collect the manure dropped over night carefully, and preserve it in a heap until sufficient for sale accumulates. The manure is readily saleable to ordinary cultivators and particularly to those who grow market garden crops under well irrigation. Nurserymen and private owners of gardens also buy sheep or goat manure freely for plants in pots, more particularly for roses. The price paid is usually about Rs. 3 per cart-load. Usually it contains a good deal of sand or earthy material.

Analysis.

A sample of pure, dry sheep dung analysed by Dr. Leather contained 1·6 per cent. of nitrogen (6·5 per cent. moisture) and the following is an analysis of fresh sheep dung by the Agricultural Chemist, Government of India :—

Water	57·75
*Organic matter	15·86
Ash	26·39
*Nitrogen	·848
P_2O_5	·059

GREEN MANURING.

The soils suitable and the value of the system generally described.

The term is applied to a practice of growing a crop for the express purpose of ploughing it into the soil on which it grows, and before it has reached maturity. This system of manuring is cheap, effective and within the means of any cultivator in India. A quick growing crop and one that covers or shades the ground is considered best. The direct effect of green manuring is to enrich the surface soil particularly if the roots of the crop grown have a considerable range and are able to collect in the subsoil sufficient plant food to ensure a vigorous growth. From the atmosphere is got much of the organic matter which green manure adds to a soil. The lighter descriptions of soils are much improved ; but green manuring is also serviceable on heavy clays. A mass of vegetable matter decaying in the soil makes heavy land more friable, and causes chemical changes whereby soluble mineral matter is liberated from compounds previously dormant. Decaying organic matter warms a soil. The humus formed conserves moisture as well as the soluble manurial substances and draws direct from the atmosphere free ammonia. In India, one of the many advantages of green manuring is that surface weeds are suppressed, if a crop that completely covers the ground is grown.

The seasons suitable.

A green manure crop is a preparation for another crop, the latter being the principal one. It is imperative that the green manure should be ploughed into the ground at least a month before the principal crop is due to be sown. This gives the proper time for decay. In practice a longer period must elapse under certain conditions. As a preparation for a cold weather (*rabi*) crop it may be sown in the monsoon and ploughed in 2 or 3 months after. As a preparation for a rain (*kharif*) crop it is best to sow about the time the cold weather crops are usually sown, while there is yet sufficient moisture for germination. The crop should be ploughed in during December or January. By the decay of the green manure during the succeeding hot weather, the land is got into a fine open mellow condition for sowing when the June rains come. Green manuring is not much practised during the *rabi* season, because the rainfall is precarious, and sufficient moisture to secure a vigorous growth is important. Unless the crop shades the ground and smothers surface weeds a good deal of the benefit is lost.

The most suitable green manure crops.

There are several crops that may be grown as green manure. The two most common are horse gram (Dolichos biflorus) and Bombay hemp (Crotalaria juncea). Both belong to the natural order leguminosæ. Plants of this family fix free nitrogen in a manner already fully described, and the two crops named, by the decay of their roots, stems and leaves, leave the surface soil much richer in organic matter, in nitrogen, and to a less extent in the other elements of nutrition than before their growth. In the garden lands of Gujarát it is common to grow *guvár*

(Cyamopsis psoraloides) amongst ginger, turmeric, and other irrigated garden crops. When the *guvár* is about 4 feet high many of the plants are up-rooted, broken up by hand and laid on the soil surface as green manure amongst the ginger, turmeric, &c., plants. The *guvár* plants which are left standing about 2 to 3 feet apart are also stripped of their side leaves. These leaves also are laid as green manure on the soil and with irrigation very rapidly decay. Horse gram commonly called *kulthi* is, perhaps, the best crop to grow for green manure in the *rabi* season, because it thrives well with very little moisture. It is as green manure a common preparation for sugar-cane in the Deccan: and for this purpose is usually sown in August, September, and ploughed in November. If the land is moderately light it is sown in June or early in July, and ploughed into the soil when in flower in September, but on heavier soil it cannot stand much rain and is therefore sown later in the season. *Kulthi* is a light or moderately light land crop, more suitable as a green manure crop than any of the other pulses of trailing habit of growth, because it grows well on such land, and because its stems and leaves are very soft and cellular, and therefore quickly decay when ploughed into the soil. On heavy soil *udid* (Phaseolus radiatus) thrives better than *kulthi* and is therefore a better green manure crop on such land. Indigo is often grown as a green manure crop. It also belongs to the leguminosæ.

In Madras and in parts of the Konkan the green leaves and young branch wood of certain trees and shrubs are collected and strewn on the surface of the rice fields after the seed is sown and answer the purpose of green manure.

The method of green manuring.

The most common green manure in the Deccan is *san* (Bombay hemp). Sown in June-July, it is allowed to grow for two months. By that time it has acquired a height of 3 to 4 feet. A roller consisting of a log of wood or a plank should precede the plough to level the tall mass of vegetation. In this way the crop is partially buried, and can be completely so, if a couple of women follow the plough to lay the plants so that the next furrow will cover them. The reason why green manure is ploughed in, while yet in a young and succulent condition, is that the cellulose which forms the main bulk of the crop is at this stage in a condition to readily decay, while at a later stage it would be converted into woody fibre which is less distructible. The crude cellulose of Bombay hemp is the fibre which is used for rope making. A mature crop is valuable for its fibre.

Analysis.

A crop of Bombay hemp when ready to be ploughed in as green manure would in its green succulent state certainly weigh 10 or 12 tons

per acre, and a very good thick crop a good deal more. The value of the crop as manure may fairly be gauged by the following analysis (Dr. Leather) :—

Moisture...	65·85
* Organic matter ...	30·35
Alkalies, Phosphates, &c.	2·39
Insol. Sil. matter	1·41
	100·00
* Containing Nitrogen	·526

Dr. Leather found the following percentages of nitrogen in various green manures grown at the Cawnpore Farm :—

Mug (Phaseolus Mungo)	·396
Udid (P. Radiatus)	·401
Do. Do.	·452
Kulthi (Dolichos uniflorus)	·391
Indigo (Indigofera tinctora)	·745
Do. Do. Do.	·873

FISH MANURE.

Fish manure used mostly for particular crops.

Coarse fish caught in quantity on the Thána coast and elsewhere in the Bombay Presidency are sun-dried and transported inland as manure in coarse sacks. In sugar-cane culture this manure is much valued. In the garden culture of Bassein where betel-vines, ginger, turmeric and plantains are the principal crops, fish in a rotten and decomposing state is applied to the land. In the cultivation of *nágli* (Eleusine coracana) in coast districts, the holes made for transplanted seedlings are half filled with manure of some sort before the seedlings are inserted. A piece of dried fish in each hole is the common manure used.

How the manure is prepared.

The dried fish obtained from the Thána coast are slightly salted probably with sea water. They are dried on the beach and on this account are generally found mixed with a considerable proportion of fine sand. If fish manure is dried without salt it decomposes very readily, and a most offensive odour is evolved. Decomposition occurs most rapidly when the air is moist. There should be no delay in applying fish manure to the soil and it should be ploughed in at once otherwise jackals, dogs, pigs, crows, &c., are attracted to the field.

Value and composition : Application per acre.

Fish manure is worth in Poona about Rs. 40 per ton, and at this price is undoubtedly cheap. It is rich in nitrogen, phosphoric acid, lime and potash, all present in readily available form. Therefore it is an active manure

and for sugar-cane is very effective either used alone at the rate of 2 to 4 tons per acre or as a top dressing applied after the crop has made some progress. One ton of fish manure is given as a top dressing for sugar-cane in addition to other manure applied before plantation. And a like quantity would be sufficient dressing for ginger, turmeric or other ordinary garden crops.

Manufacture of fish manure in Europe.

In Europe fish undergo some treatment before being sold as manure. Usually the waste from fish curing factories only is utilized. The flesh, bones and offal are desicated and ground to powder and mixed with kainit (a mineral manure got in Germany and chiefly valuable for the potash it contains). This constitutes fish-potash-guano. Its composition varies but the kainit not only acts as a preservative but also adds potash and magnesia to a manure which is already rich in nitrogen, phosphoric acid and lime.

Dried fish of the Malabar Coast gave the following analyses :—

Analyses.

Dr. Leather.		Collins' "Agricultural Chemistry".	
Moisture ...	5·72	Moisture ...	10
* Organic matter ...	58·27	Organic matter ...	50
† 3 (Ca O) P_2 O_5 (Tricalcic Phosphate) ...	16·88	Nitrogen ...	6·8
Carbonate of Lime and Alkalies ...	11·01	Phosphoric Acid ...	6
Sand ...	8·12	Potash ...	·7
		Lime ...	10
Total	...100·00		

* Containing Nitrogen ... ... 8·04

† Containing P_2 O_5 ... ... 7·73

GUANO AND ALLIED MANURES.

Deposits of guano how formed.

The excrement of fowls and pigeons is a highly concentrated manure. A good English farmer takes the trouble to strew the floors of the fowl house and pigeon loft with fine earth, sand or ashes. This material with the droppings is removed at least twice a week and kept under cover until required for use. Guano is a manure similar to pigeon dung. It is the accumulated excreta of numerous sea-fowls and is found on rocky islets in parts of the world where rain seldom falls. The droppings of myriads of birds, with the remains of the fish which they caught and ate, and their own dead bodies have, during untold ages, accumulated into enormous deposits. The manure has retained its original manurial value, because there has been no rain and no waste from drainage has occurred.

The characteristic appearance of good guano is sometimes skilfully imitated. The most common adulterations are sand, gypsum, brick dust, ground coprolites and common salt.

Adulterations.

Guanos are sometimes treated with sulphuric acid. This renders the ammonia which exists usually as crystals of carbonate of ammonia non-volatile, because sulphate of ammonia is formed. The tricalcic phosphate is converted into the monocalcic soluble phosphate, while the organic matter is rendered more decomposable. Nitrogenous guano is not now so rich as it used to be ; the best deposits have been exhausted. It rarely now contains more than 12 per cent. nitrogen.

Guanos are sometimes treated with sulphuric acid.

It is one of the best manures for wheat. An application of 2 to 3 cwts. per acre is enough. It acts rapidly. Its immediate effect is easily observable. Nearly all its action is expended upon the crop to which it is applied. It is a good manure for any crop that it is desirable to force into vigorous growth, particularly potatoes.

Guano of a sort is not unknown in India. Guano in considerable quantity but of unknown composition is known to exist in certain caves in the Kurnool district and elsewhere. The guano of the swallow caves of the Nicobar Islands can be obtained by the ship-load, and is used to some extent by tea planters in Assam.

SEA-WEED.

A manure which is somewhat similar in its effect to green manure is sea-weed. There is no sea-weed on the Bombay coast. But on many coasts it is collected in immense quantities, particularly after high tides and storms, and is applied to land at the rate of 20 to 30 cart-loads per acre. It is recognized as a good manure for potatoes. This we can readily understand, because it is rich in potash. The ash of some species of fucus (sea-weed) contains as much as 20 per cent. of potash. The ash of sea-weed is called kelp, and at one time the practice of burning sea-weed was a regular industry connected with soap making. Sea-weed readily decays in a soil because its tissues are almost entirely cellular. The organic matter and nitrogen which it furnishes are each valuable ; so also are the appreciable quantities of phosphates, lime, magnesia and common salt. It is often composted with farm-yard manure and earth. It is a good manure for light land and has about the same manurial value as farm-yard dung.

Apart from its manurial value, sea-weed has a powerful influence in freeing land of grub and the larvæ of destructive crop pests. It is probably the salt which it contains to which this effect is due. The same ingredient makes sea-weed a suitable manure for such crops, as are naturally seaside plants, such as, asparagus and beet.

COMPOSTS.

Composts are of variable composition, and may be regarded as the savings bank of the farm. The careful cultivator in times of leisure deposits there all waste rubbish. In the course of a year this will accumulate to considerable dimensions. The heap should include weeds, sweepings, pond-mud, the clearings of water channels, road scrapings and the carcases of animals dying on the farm. The last should be cut up into pieces. The whole should be mixed with soil and caustic lime. The lime should form at least one-sixth part of the bulk of the whole heap, and it should be laid in alternate layers with the material composted. If the heap is kept sufficiently moist and turned once, a short period before being used as manure, heat will be generated, decay will occur, and a friable homogeneous mass will form which may be accounted a valuable manure. It should be applied at the rate of 20 to 40 cart-loads per acre, according to its actual manurial value. What is known as pit manure in India, consisting as it does of sweepings and household waste, ashes &c., is a variety of compost. If such is kept moist by the urine of animals, it proves a valuable fertilizer. No lime is used.

BONES.

Not generally used in India for reasons given.

There is a very large supply of bones available in India for use as manure or for export. They have not been used to any extent as manure by Indian *rayats* and are not likely to be until by some cheap method they can be dissolved and made more quick acting than in their natural condition. Experiments on Government farms and elsewhere indicate generally, that for ordinary dry crops, also for irrigated crops, especially the former, bone manure, though in the form of a fine powder, is extremely slow in its action. The action is so slow that it does not pay to use bones even though procurable at a cheap rate of, say, Rs. 20 a ton. In out-districts which are remote from railway communication bones can no doubt be obtained in quantity at even a cheaper rate, but owing to the keen demand for export the price is high along all lines of railway near important seaports. In Bombay bone meal is worth Rs. 50, sometimes as much as Rs. 60 per ton, and at this price it will certainly not pay the Indian *rayat* to use it. He would be very foolish to do so because, he can buy oil-cakes and other manures which are much more effective at a much cheaper rate. It was believed at one time that the caste prejudice which exists against the use of bones as manure was the chief reason why they were not so employed. This I do not believe to be the case; for, if bones either dissolved or otherwise could be proved to be a cheap and effective manure for any description of crop the caste prejudice would disappear, just as it has done in the case of poudrette.

Bones consist of a mineral portion and an organic portion in the ratio of 2 to 1. The mineral portion is largely composed of the phosphates of lime and magnesia with a little carbonate of lime and alkaline salts notably those of potash and soda. The organic portion is to some extent nitrogenous and is made up of gristle, gelatine, and fat. Raw bones contain about 4 per cent. nitrogen and 50 per cent. phosphate of lime. But they usually undergo some treatment before being presented to agriculturists as manure. The fat they contain retards their decomposition in the soil, and is valuable for soap making. The gelatine is in request for the manufacture of glue. Gelatine is soluble in hot water. If bones are boiled much of the organic portion is removed. If subjected to the action of superheated steam nearly all is extracted. In India nature practically accomplishes this, partially by the heat of the sun and its bleaching effect; but most because the organic portion is fed upon by ants. These insects leave little except the indigestible mineral matters, that is, bone earth.

Composition of bones.

Bones are usually reduced by machinery into bone meal or into larger fragments of variable size. Bones if fairly dry can be ground into fine powder at little cost under the stone of an ordinary chunam or mortar mill. The *rayat* could, if he took the trouble, collect in some districts quantities of bones, the cost of which would be cartage and his own labour. He could grind the bones into powder in the manner indicated above and by a simple process of fermentation make the bones more soluble and, therefore, more quick acting than in their natural condition. If these operations were conducted in the *rayat's* spare time and the value of his labour more or less discounted, I have no doubt that the bone manure would be found as cheap as any other manure procurable. The method of fermentation which I would recommend would be as follows:—A pit should be dug at least 4 feet deep. Crushed or powdered bones should be thoroughly mixed with at least double the quantity of good loamy soil. The mixture should be put in the pit and kept moist by adding from time to time urine or urine and water. The bones and urine will each ferment. A certain amount of heat will be generated and carbonic acid gas given off. The bones are softened and partially decomposed. The nitrogenous compounds of the urine and also of the bones are at least in part converted into ammonia combinations and finally into nitric acid or nitrates. If the earth used is of a loamy character the ammonia evolved from the fermenting urine and bones will not be lost. The mass in the pit should be exposed to the atmosphere but be protected from rain and should be turned several times during fermentation. This will admit the oxygen of the air and hasten decomposition. The fermentation will take 6 or 8 months to complete. During the process the almost insoluble tricalcic phosphate will be partially converted by the chemical

The preparation of bones for manure.

effect of carbonic acid into monocalcic phosphate—a more soluble phosphate of lime, but what is perhaps more important still, the structure of the bone fragments will be made porous so that the air and moisture of the soil can have free scope to make each fragment more soluble.

Slow action as manure

The finer the bones are pulverized the quicker is their action in the soil; but at the best it is slow and particularly so in India. It extends over many years. Tricalcic phosphate gets soluble by degrees through the action of nitric acid and carbonic acid in the soil and in contact with the acid juices of the roots of plants.

Analyses.

I give below two analyses by Dr. Leather of bone meal. The first analysis is of a pure sample being particularly free from sand, an impurity which is usually present in large proportion in Indian samples. The second sample contained a high percentage of sand and the impurity is clearly due to deliberate adulteration :—

	Pure bone meal.	Bone meal, inferior sample.
Moisture	7·75	6·55
*Organic matter	29·55	21·46
†3 (Ca O) P_2 O_5 (Tricalcic Phosphate)	53·74	30·24
Carbonates of Lime & Alkalies ...	8·67	13·92
Sand	·59	27·83
Total ...	100·00	100·00
*Containing Nitrogen	3·68	2·42
†Containing P_2 O_5	24·63	13·85

DISSOLVED BONES.

Dissolving bones with sulphuric acid.

This is a preparation obtained by treating raw bones with sulphuric acid, which causes the action of the bones as manure to be quickened. The tricalcic insoluble phosphate is converted into the monocalcic phosphate which is soluble in water. Nowadays superphosphate is seldom made from bones. Mineral phosphates are cheaper and have of late years been largely substituted for bones. The decomposing action of sulphuric acid is partially shown by the following formula :—

$$3\ (Ca\ O)\ P_2\ O_5 + 2\ H_2\ S\ O_4 = 2\ Ca\ S\ O_4 + Ca\ O\ (2H_2\ O)\ P_2\ O_5$$

Tricalcic Phosphate+Sulphuric Acid=Gypsum+Monocalcic Phosphate.

The effect upon phosphate of lime is represented above, but sulphuric acid exercises a further effect upon the organic nitrogen which is changed into a more soluble form.

In making bone superphosphate it is not usual to add enough acid to completely dissolve the tricalcic phosphate. If much acid is added the resulting

manure is pasty and unmanageable. Bones can conveniently be dissolved on the farm as follows:—The bone meal or bone fragments should be placed in a wooden box or trough to a depth of not more than 8 to 12 inches and well moistened with water. Sulphuric acid of ordinary commercial strength should be poured over the mass—1 part by weight of acid to 5 of bones. Chemical action begins at once, heat is generated, steam and fumes given off. During this action the mass should be well stirred with a pole or stick. The object of moistening the bones is to attract the acid to each bone particle, sulphuric acid having a great affinity for water. When the mass cools down it may be exposed in a thin layer to the sun to dry. As it dries the lumps can be powdered by hand. Dissolved bones prepared in this way at the Poona Government Farm show the following analyses (Dr. Leather).

Analyses of bones partially dissolved.

	1st Sample.	2nd Sample.
Moisture	8·35	4·69
*Organic matter	32·41	31·59
Monocalcic Phosphate ($CaO. P_2O_5$) ...	2·58	4·75
Insoluble Phosphates	40·32	39·99
$CaSO_4$, &c.	13·14	18·16
Sand	3·20	·82
	100·00	100·00
*Containing Nitrogen	3·23	3·31

The object of dissolving bones is to get the phosphate of lime into finely divided particles, much finer than can be accomplished by any mechanical power. It is obviously the fineness of the particles that is the most important consideration, because we know that the soluble monocalcic phosphate in contact with alumina or oxide of iron becomes again insoluble, and all soils contain alumina and iron. 3 to 4 cwts. of dissolved bones is a fair application per acre for ordinary crops.

MINERAL PHOSPHATES.

Origin and position.

Mineral phosphates of variable composition are found in various parts of the world. When found in a crystalline form the mineral is called apatite, and contains a high percentage of phosphate of lime. When found in beds which are not crystalline it is known as phosphorite, which is of very variable composition. Phosphatic nodules called coprolites are found in England, in the aluvium of the Jamna river, and in other parts of the world. These are supposed in some instances to be the fossil bones and excreta of prehistoric mammals, whilst the finest varieties when split show the imprint of the scales and bones of fish which clearly indicates their origin.

Phosphatic nodules contain generally 52 to 62 per cent. of tricalcic phosphate of lime and 20 to 30 per cent. of carbonate of lime, the other impurities being iron, alumina, sandy matter and sometimes fluorine. The purest form of phosphatic mineral contains over 80 per cent. of tricalcic phosphate.

Phosphatic minerals treated with sulphuric acid.

Mineral phosphates are invariably treated with sulphuric acid and converted into superphosphate before being employed as manure. If the raw material contains much carbonate of lime, iron oxide, alumina, &c., it is considered inferior in quality by manufacturers, because these substances tend to waste the sulphuric acid necessarily required to dissolve the tricalcic phosphate. In other words if the phosphatic mineral is fairly pure, a smaller proportion of acid is required to dissolve it than if much impurity is present. Iron and alumina are more objectionable impurities than carbonate of lime, because they require a great deal of acid to dissolve them, and if they are left unacted upon they have a tendency to make again insoluble the monocalcic phosphate produced by the action of sulphuric acid on tricalcic phosphate.

Superphosphate.

The first process in the manufacture of superphosphate is the reduction by machinery of the crude phosphate to a fine powder. The pulverized material is placed in the "mixer." The necessary amount of acid is allowed to flow in in small quantities at a time. Carbonic acid gas, hydro-fluoric acid, (HF) and Silicon tetra-fluoride, ($Si\ F_4$) &c., are given off. These vapours are more or less poisonous to animal and vegetable life, and in factories are passed through flues having jets of water which condense the injurious ingredients. In the mixer the acid is well mixed with the ground phosphate by means of blades attached to a revolving shaft. When all the acid has been added the bottom of the mixer is removed and the contents allowed to fall into an underground chamber called the "den." This when full is closed and left so until the temperature has cooled down and all chemical changes have ceased. The superphosphate is afterwards dug out and passed through a disintigrater before being sold. In ordinary superphosphate $\frac{1}{6}$ to $\frac{1}{3}$ of the tricalcic phosphate is left undissolved. The chief reason for this being that if much acid is used the resulting superphosphate is almost certain to be pasty and therefore not easily converted into a friable powder, this being the best condition for even distribution when applied to the soil. Superphosphate is of very variable composition. If made from coprolites it should usually contain

		Per cent.
Tricalcic Phosphate $3\ (Ca\ O)\ P_2\ O_5$	...	7 to 8
Monocalcic Phosphate $(Ca\ O)\ P_2\ O_5$	...	19
Gypsum $Ca\ S\ O_4$	...	42

It is essentially a phosphatic manure, and on this account is probably of doubtful value for ordinary Indian soils. Mineral superphosphate is, however, often made the basis of a general manure, salts of ammonia or nitrates being added to supply nitrogen and kainit or other available potash manure to supply potash. The general manure thus formed has been proved effective for almost all descriptions of crops. If superphosphate were manufactured in India a good general manure could be got by simply adding nitre (nitrate of potash) which in its crude form is obtainable in many parts of India.

Superphosphate mixed with other manures to make a general manure.

When superphosphate is added to a soil the soluble phosphate is almost at once precipitated by the lime in the soil, first as bicalcic phosphate, and then as tricalcic phosphate. It finally combines, if not utilized by a crop, to form the still more insoluble phosphates of iron and alumina. The precipitated phosphate is believed in the first instance to be in the form of a jelly in which state it is much more soluble in soil-water than it was originally. It is therefore diffused more easily and completely through the soil and this is the chief advantage gained in making it soluble. Fossiliferous beds of coprolite and other phosphatic minerals are known to exist in large quantity in various parts of India.

The action of superphosphate in the soil.

BASIC SLAG.

A phosphatic manure which of late years has come into prominent notice in Europe is called Basic Slag or Thomas Slag. It is a by-product in making steel by the basic process. This process is an improvement on the old Bessemer process. In the manufacture of steel from pig-iron certain impurities have to be removed notably phosphorus which causes steel to be brittle. The method of purifying is ingenious. Pig-iron is fused at a very high temperature. Lime is mixed with the molten metal. Air is forced through the molten mass. It oxidizes the phosphorus into phosphoric acid which combines with the lime and rises with the other impurities to form a scum. This scum is basic slag. It is of variable composition.

A by-product in the manufacture of steel.

It may contain (Aikman's analysis)

Analysis.

Phosphoric acid	17	per cent.
Lime as Silicate, Phosphate, Sulphate and Carbonate	40	„
Free Lime...	15	„
Oxides of Iron	12	„

It requires to be pulverized for use as manure.

The peculiarity of the phosphate of lime as it exists in basic slag is that unlike that found in nature, it has four molecules of lime combined with one of phosphoric acid, and further, this tetra-phosphate is much more soluble in soil water than the tricalcic phosphate. This was not appreciated to begin with, and various expensive methods were patented for purifying, making soluble, and otherwise manufacturing into manure what appeared to be a most insoluble form of phosphate of lime. Subsequent experience proved that machinery capable of grinding the crude slag into a fine powder was all that was necessary. A valuable phosphatic manure is now prepared in this simple manner and largely used. Its phosphoric acid is not so valuable as that in superphosphate, although wonderfully favourable results have been obtained with it on soils of an organic character and on clays poor in lime. This is doubtless due to the energetic action of the free caustic lime it contains, the presence of which should caution the farmer against its use in conjunction with manures from which free ammonia might be liberated. 5 cwts. per acre is a liberal application.

NITRATE OF SODA.

A product of South America.

Extensive beds of this mineral are found near the surface in rainless tracts of Chili, Peru and other parts of South America. The salt as it is mined is impure. The crude material consists of nitrate, chloride, and sulphate of soda with gypsum, etc., and contains never more than 60 per cent. of pure nitrate of soda, often half that quantity. These beds of salt cannot be accounted for in the same way as the *reh* incrustations in India. They are found between a superlayer of sand and a substratum of impervious clay conglomerated with various salts which make it still more impervious to moisture. A dried-up sea, it is supposed, once held these nitrate, etc. salts in solution.

Composition and value.

Purified nitrate of soda should contain 96 to 97 per cent. nitrate of soda, equivalent to 15·5 per cent. nitrogen. It is essentially a nitrogenous manure and was worth formerly in England £ 11 to £ 12 per ton; now (1900) it is worth about £ 7-10 per ton. Nitrate of soda somewhat resembles common salt in appearance, and there is a tempting inducement to adulterate it with that cheap material by unscrupulous dealers.

Application as manure.

Nitrate of soda is a very effective manure for cereals, especially if applied in a cold backward season when the plant appears sickly and unthrifty. Two cwts. per acre is a heavy application; one cwt. is an ordinary one. To secure even distribution it should be broadcasted mixed with double its bulk of ashes or common salt. The tendency of nitrate of soda is to increase the length and weaken the straw of a wheat crop or any cereal, and common salt checks this tendency. Nitrate of soda being extremely

soluble should not be applied in rainy weather. Rather apply it when the soil is moist, and as a top dressing. A growing crop will take much of it up at once. The effect of nitrate of soda does not extend beyond the crop to which it is applied. It is recognised as a power in the hands of a capable farmer whereby the soil is stimulated to yield up a considerable quantity of its available potash and phosphates, and produce heavy crops. It can only produce its full effect when there is sufficient potash and phosphates in the soil. Under other circumstances it is wasted in the drainage or produces a good deal of straw and very little grain. It has been proved that fractional dressings applied at intervals of a month are much more beneficial than the aggregate of these quantities applied at one time. Nitrate of soda exercises an extraordinary effect upon the foliage of crops, causing a marked change in the colour of the leaves, a few days after its application. This is strikingly shown where the salt has been unequally broadcasted or where a strip across a field is left purposely unmanured to show the effect. The crop on the area to which the nitrate has been applied acquires a deep green colour, while the unmanured portion remains pale and sickly. There is little doubt that to a growing crop and in the absence of heavy rain, nitrate of soda is the most effective salt of nitrogen that can be applied. It rapidly diffuses through the soil, and if it does sink deeper than the range of roots, it encourages these to send their rootlets deeper and thereby acquire a wider range to collect moisture and the plant food they seek after. The nitrate is undoubtedly the most valuable form of combined nitrogen when any of the conditions necessary to nitrification are absent. It is doubtful, however, whether it is the most economical form in a wet season. If immediately after its application much rain follows, on account of its extreme solubility, it may be washed away in the drainage before plants have time to take it up. Under the most favourable circumstances, three-fourths only of the nitrogen of any very soluble nitrogenous manure is utilized by a crop ; the rest is lost in drainage.

Has a quick acting stimulating effect.

SULPHATE OF AMMONIA.

Sulphate of ammonia, although quite soluble in soil water, does not distribute itself through the body of a soil nearly as quickly as nitrate of soda does, and therefore cannot come so soon in contact with the roots of plants. It is not so liable to be washed out of a *good* soil in wet weather, because the soil particles can hold ammonia salts until nitrification occurs, or the ammonia may combine with organic acids or silica present and thus be held in the soil.

Not so soluble a nitrate of soda and not so readily lost in drainage.

Sulphate of ammonia is indirectly a by-product in the manufacture of illuminating or coal gas. This is its principal source of supply. It is also prepared by distillation from blood and other animal matters. Coal contains

A by-product in the manufacture of coal gas.

varying quantities of nitrogen—from a trace to 2 per cent. and usually about one per cent. When distilled, half of this is given off as ammonia, which with some other impurities is intercepted by the gas water. This ammonia water of gas works contains ½ to 1 per cent. ammonia, partly as free ammonia and partly as chloride, carbonate and sulphate. The gas liquor can be used directly to crops if diluted. In the neighbourhood of large towns, it is valued for market garden crops ; or the ammonia may be driven off from the gas water and absorbed by sulphuric acid.

Composition and value; application per acre.

The ammonia sulphate of commerce should be 93 to 97 per cent. pure which is equal to about 20·5 per cent. nitrogen. This quality is now (1900) worth in England £ 8-10 per ton. Formerly it was sold at a much higher price. 1 to 1½ cwt. per acre is a liberal dressing. It is a quick acting manure and is much used for mixing with phosphatic and potash manures to form a special manure for certain crops. Alone it is commonly applied as a top dressing and should be mixed with several times its own weight of ashes, salt, etc., but should never be mixed with or used at the same time as any manure containing free lime.

GYPSUM.

Found extensively in India.

Gypsum is a sulphate of lime with water of combination. It is found in large deposits in Cutch and in the form of selenite in Káthiáwár and in a crude form in the Deccan. In the Poona district it is collected, cleaned, heated on an iron pan, powdered and then used like lime for whitewashing walls. Gypsum exists in enormous deposits associated with rock salt in the Kohat district, and is also found in enormous quantities in the Salt Range.

The refuse gypsum of soda-water manufactories has been used experimentally with success as manure on the Saidápet farm ; but nowhere in India is its value as manure appreciated by the ordinary cultivator.

Extensively used as manure in America.

Gypsum is rarely used in European countries except as an ingredient of special manures probably because superphosphate which contains over 40 per cent. gypsum is in much request. In America and Canada, it is often applied alone and all leguminous crops are there immensely benefited by applications which vary from 2 cwts. to 2 tons per acre. Part of its action is attributed to its power of fixing ammonia in the soil. This is probably erroneous. Its effect in this respect is, however, often taken advantage of by careful farmers who sprinkle the floors of their stables and byres with gypsum in order to arrest the loss of ammonia from decomposing urine. Gypsum like lime assists in dissolving rock material.

POTASH MANURES.

A glance at the analysis of the ash constituents of all agricultural crops shows that potash is one of the most important elements in manure. It is present in the ash of some plants to a greater extent than in others. Tobacco, all the pulses, indigo, flax, beets, potatoes, brinjals and many other garden crops contain a high percentage of potash in their ash and are naturally much benefited by potash manures. Wood ashes contain much lime and potash. The burning of cowdung, although otherwise wasteful, fortunately conserves from loss the potash, which all remains in the ashes, and probably the action of the fire makes the potash more soluble. These ashes are preserved ordinarily in a pit by the *rayat* with the sweepings, the household refuse and sometimes the urine of the cattle, and form what is called pit manure. This usually is the only manure applied to the land. It is probable that the soils in India, particularly the black soils, are better stocked with potash than with any other of the more essential elements. All the same it behoves the careful husbandman to take every opportunity of storing all waste material that is known to contain this or any other manurial element. Rice husk almost worthless as a cattle food and often burnt as a material of *ráb* is rich in potash. So also is the refuse, ash and skimmings in the process of *gul* making. Indigo plants from which the dye has been extracted and even the water from the vats should be utilized for manure. Indigo refuse is not only rich in potash but also in nitrogen. Dr. Leather found in fresh indigo refuse ·763 nitrogen and 50 per cent. water.

Specially valuable for particular crops.

Indian supplies.

Potash minerals more or less impure are mined in Germany principally near Strasfort. There the following potash salts are found :—

Potash minerals.

1 Carnallite.—A chloride of magnesia and potash with six equivalents of combined water.

2 Sylvine.—Chloride of potash.

3 Kainit.—Chloride of potash, sulphate of potash, chloride of magnesia, sulphate of magnesia with six equivalents of combined water.

Crude kainit is largely used as an ingredient of special manures and is worth £ 2 to £ 3 per ton in England. It should contain 13 to 14 per cent. potash. When it is calcined the water of combination is driven off, and the percentage of potash increased to 17 or 18 per cent. Kainit is a good manure for potatoes, clovers and grasses, and 2 to 4 cwts. per acre is the usual application. It is more useful on light lands than on clays. The magnesia salts which it contains are probably of some value.

Composition and value of kainit.

NITRATE OF POTASH.

A natural product in various parts of India.

Saltpetre or nitre is found with common salt and other salts of sodium impregnating the soil in many parts of India, and is often found encrusted at or near the surface. In *reh* tracts the salt efflorescence contains very little nitrogenous salt, but in some places the percentage is considerable. The largest supply is found in Behar, but there is a considerable industry in the manufacture of crude saltpetre generally throughout the North-Western Provinces, also in Madras. The site and surroundings of old depopulated villages furnish a considerable supply. In these situations the solid and liquid excreta of men and domesticated animals, the village sullage, the household wash and fuel ashes become incorporated with the soil and subsoil. By the nitrification of the organic matter nitric acid has been formed which has combined with the potash of the ashes, etc. In rich, deep, good land, particularly if of a clayey character, the soil material may itself yield saltpetre by nitrification. The crude nitre salt becomes encrusted at or near the surface during the fair season ; because then the moisture of the subsoil rises by capillarity and is evaporated away at the surface leaving there the salts which it held in solution. A thin upper layer of soil impregnated with salt may be scraped off and utilized in the manufacture of saltpetre and this may be repeated season after season until the soluble salts in the soil and subsoil are exhausted.

A specially valuable manure for particular crops.

Saltpetre when locally obtainable at a reasonable price can be used with every advantage as manure being especially effective for tobacco, sugar-cane, potatoes, brinjals and some other garden crops. Its cost, however, is generally prohibitive against its use as manure, except for valuable garden crops, such as those named above, which usually yield a valuable outturn if carefully cultivated and liberally manured. Saltpetre with 5 per cent. impurity can be bought in Poona at Rs. 14 per cwt., and crude saltpetre containing 10 per cent. impurity at Rs. 10 per cwt. Crude saltpetre in districts where it is manufactured varies in prices from Rs. $3\frac{1}{2}$ to Rs. 5 per cwt. but its composition is variable and uncertain.

Value.

Analyses.

The following are analyses by Dr. Leather of crude saltpetre bought in the Poona bazar and used as manure in the Mánjri sugar-cane experiments.

	1st Sample.	2nd Sample.	3rd Sample.	4th Sample.
Moisture	5·98	3·36	1·50	1·90
KNO_3.	68·50	66·62	86·37	66·95
Na Cl.	19·49	22·57	10·39	26·58
Na_2SO_4	5·43	7·15	1·64	2·42
Sand, &c.	·60	·30	·10	·15

Manufacture of altpetre.

The process of manufacture essentially consists of a filtered solution obtained from the salt soil being boiled down to the point of crystallization.

Meantime impurities are removed by skimming. The nitrate of potash separates from the more or less worthless sodium salts as the liquor is cooled, because the nitrate of potash is less soluble in cold water than in hot; whilst common salt is equally soluble in both. In practice it is found that by simple evaporation the nitre cannot be separated completely from the sodium salts and on this account it sometimes contains as much as 50 per cent. impurity.

For ordinary crops 1 to 2 cwts. per acre of nitre is sufficient. It has not been used to any extent as manure by ordinary cultivators. The *rayats* in the North-Western Provinces use canal mud and salt impregnated earth as manure for ordinary crops.

Use as manure.

COMMON SALT.

Experiments have shown that common salt is valueless as supplying soda to plants, but that it is useful as a source of chlorine. It is more necessary for some crops than for others. Plants which grow naturally near the sea necessarily require it. The price of salt in India prevents its use as manure. Districts bordering the sea receive in the rainfall for a considerable distance inland as much common salt as the cultivated crops require. The brine which bacon curers and fish curers have used when it is evaporated to dryness gives the best agricultural salt, because it contains blood and other animal nitrogenous matters.

Valuable as manure for particular crops and under special circumstances.

The application of common salt in conjunction with nitrate of soda, in order to modify the stimulating effect of the nitrate, has already been noticed. Common salt is recommended for killing larvæ and insects in the soil. It has doubtless some action upon the mineral portion of the soil which is not well understood, and, applied in quantity, it kills vegetation. This power is taken advantage of sometimes when deep rooted weeds occupy spots in a field, and otherwise are difficult to destroy.

SOOT.

Soot is a carbonaceous substance containing a small percentage of ammonia, usually 2 to 3 per cent. The organic portion of soot may have a slight value. Soot is worth in England £ 1 to £ 1-10 per ton. The price is higher than the manurial value of soot warrants. But as a top dressing for wheat it is used largely where injury to a crop is feared from the attacks of wireworm or grub. It certainly destroys these pests and for this propose as well as for its manurial value it is applied at the rate of 10 cwt. per acre. It is often used in gardens especially for onion beds, as a specific against the

OIL-CAKE MANURES.

The value of oil-cakes made by country *ghání* and hydraulic presses contrasted.

There is a large export trade in oil-seeds from India. There is also an import trade in oil, particularly linseed oil. It is likely that the import trade will diminish because of the extended use of improved oil pressing machinery in India. In Bombay, hydraulic oil presses are in use in several mills, but generally throughout the country the old fashioned village *ghání* is still much in evidence, and by this means the greater portion of the oil got from oil-seed in India is expressed. The residue left when oil is expressed from oil-seed is known as oil-cake. Oil-cake which has been subjected to hydraulic pressure is known as hard pressed cake and contains a much less percentage of oil than that got from the country *ghání*. Oil-cakes have nearly all a high manurial value. The more oil that is extracted from oil-seed the greater is the manurial value of the residue and the sooner will the cake decay in the soil. The oil left in an oil-cake has no manurial value because it consists of carbon, hydrogen and oxygen. Any crop can get these elements from the water of the soil and the carbonic acid gas of the atmosphere. Moreover, the oil exercises a preservative effect excluding the oxygen and impeding those chemical changes which must occur before the cake yields available plant food. The value of oil-cake as manure chiefly depends upon the percentage of albuminoids and ash constituents which it contains, particularly the former. The less the percentage of oil the greater will be the percentage of these constituents; but in order to express by hydraulic pressure as much oil as possible it is necessary to steam or cook the seed. Heating causes the oil glands to burst and allow the oil to escape by pressure freely, but if the albuminoid matter of oil-seed is subjected to the action of superheated steam it is coagulated so to speak just as the white or albumen of an egg is coagulated by boiling and is thus made more insoluble. The albuminoids of oil-seed contain most of the nitrogen and it is reasonable to suppose that oil-cake got from hydraulic-pressed cooked seed is not so quick acting as that from oil-cake made in the country *ghání*. Another reason why it should not be so is because hydraulic pressed oil-seed is not crushed to an inpalpable powder as it is in the country *ghání*.

The country *ghání* at work.

The country *ghání* consists essentially of a pestle and mortar; the pestle grinds the seed in the mortar. The cake is consolidated by the pestle into a thick layer against the sides of the mortar and is generally removed by a short crowbar. The oil sinks to the bottom of the mortar and is soaked up in a mop and collected in a vessel, the mop being squeezed by hand. The method varies; sometimes the oil flows from the mortar as it is expressed.

It is necessary to crush oil-cakes to a fine powder before use as manure.

When oil-cakes are used as manure they should be applied in the finest possible state of division. Generally in India the pounding is done with a stick. A cheaper and equally effective method is to crush the cake under the stone

of an ordinary chunam mill. In this way a ton can be crushed at a cost of Rs. 2 to Rs. 3. The powder got from country *ghâni* cake in this way is much finer in consistence than that from hydraulic-pressed cake, and on this account the former probably acts the quickest and is the most effective as manure. The manurial value of the *ghâni*-pressed as compared with hydraulic-pressed castor cake is under experimental trial at the Poona Farm. Hydraulic pressed castor cake as made in Bombay is held by the market gardeners at Bassein (Thána Coast) to be poor stuff as manure. They have tried it. It costs in Bombay Rs. 22 per ton. They prefer to use castor cake made in Gujarát which costs in Gujarát 80lbs. per rupee, or say Rs. 30 per ton. The analysis of the two kinds shows that each contains about equivalent percentages of nitrogen and the other important elements of plant food. As suggested the difference in commercial value may be accounted for by the comparative slow action of the one and the quick action of the other. Ordinary Indian oil-cakes act quickly as manure, but [illegible] same time they last in the soil, that is, their effect extends b[illegible] to which they are applied.

Country *ghâni* cake quicker in action than hydraulic-pressed cake.

Oil-cakes are chiefly used for irrigated crops and particularly for sugar-cane, plantains, betel-vine, ginger, turmeric, brinjals, chillies, etc. It is believed to be economical to apply oil-cake in repeated small dressings rather than a full application at one time. Where possible, as for instance to plantains, the manure should be placed not far from the stems of the plants and covered with soil. In all cases it should for irrigated crops be worked into the surface soil and never covered too deeply.

Application as manure.

Some oil-cakes manufactured in India command such high prices as food for cattle or for export that they should not be used as manure. Linseed cake, sesamum cake and cocoanut cake are of this class. These are well known in European markets, and their values in India are thereby enhanced. These cakes provide specially good food for farm animals, because each is fairly rich in albuminoids and oil, and contains a low percentage of crude fibre, and therefore is easily digested. There are, however, other Indian oil-cakes which are much cheaper than the above, and are actually more concentrated as food but less easily digested. I refer particularly to safflower cake, to niger seed cake, to ground-nut cake, and to a mixed hydraulic-pressed cake made in Bombay from a mixture of safflower and ground-nut seeds. These edible cakes are cheaper than the manure cakes in ordinary use and the high percentage of albuminoid matter which they contain indicates that they can be economically employed directly as manure as long as present market rates continue. At the same time the highly concentrated character of these cakes indicates that they would be more economically used as food for farm animals, provided the solid

Certain Indian edible oil-cakes can be used economically as manure.

and liquid excreta of animals so fed are preserved with care and used as manure. Under existing conditions, this is not likely to occur, because the *rayat* fails to show that he knows that the dung of cake or grain fed cattle is any better as manure than that from half starved animals; in fact any kind of cattle dung is good enough to burn as fuel. In the hydraulic press Bombay oil mills there are usually considerable quantities of broken, mildewed and otherwise damaged cake in stock which is quite as good for manure as sound cake and can be bought at a much cheaper rate. The older and drier the cake becomes, even though the oil becomes rancid, the better is the cake for manure purposes.

Castor cake.

Manufacture.

Castor cake is the residue left when the oil is expressed from the seeds of the castor-oil plant (Ricinus communis). In the country method the seeds are soaked generally in hot water and the oil expressed by the country *ghání* from the softened seed. The oil is purified by boiling and skimming, and is only used for lighting or lubricating pu[illegible]es. The cake if eaten in small quantity by cattle acts as a purgative; in [illegible] as an irritant poison causing inflammatory disorders of the dig[illegible]t is recognised as one of the most valuable manures available in [illegible]ose districts where castors are largely grown, as for instance in Gujarát, the cake is comparatively cheap. It is worth 80 to 90lbs. per rupee. It is, however, largely exported to other districts particularly where irrigated crops are grown. In the Poona district owing to the extensive sugar-cane cultivation there is an ever increasing demand for it, and the price has about doubled between 1892 and 1896. The 1896 price was 45 to 50 lbs. per rupee. The price has remained up to date (1900) about the same level.

Value.

Used chiefly for garden crops.

Castor cake is extensively used as manure for nearly all "garden" crops and is believed not only to exercise a powerful manurial effect but also act as a preventative against the damages done by white ants which often do much harm to sugar-cane and other crops particularly in Gujarát. Castor cake is used generally as a top dressing to supplement a moderate application of farm-yard manure applied before plantation.

Application per acre and methods of application.

For sugar-cane 1 to 1½ tons per acre of the cake would be used in conjunction with 20 or 30 loads per acre of farm-yard manure. If used alone for sugar-cane as much as 5 tons per acre might be economically given, one-third before plantation, the remainder after the crop shades the ground in two or three top dressings. 2,000 to 3,000 lbs. per acre would be a liberal application of castor cake if used alone for garden crops, such as ginger, turmeric, brinjals, chillies, etc., but for plantains and betel-vines larger applications are required. For these crops the cake is most carefully applied at intervals in small quantities placed round the base of the stems and covered with soil. In Gujarát it is a common practice to steep castor cake in a vat near

the well and allow the irrigation water to flow through the mass and carry an extract of the castor cake to the crop. The castor cake becomes spent after being soaked in this way for some days. The spent residue is removed and usually is added to the farm-yard manure heap.

Castor cake if made from clean seed should contain about 4·5 per cent of nitrogen, 4 per cent. of phosphates, about 2 per cent. potash. Dr. Leather's analysis of ordinary commercial samples used at the Poona Farm gives the following percentages :— Analysis

Sample.	Nitrogen.	Phosphoric acid ($P_2 O_5$)
Country made cake No. 1	3·79	1·79
No. 2	4·13	......
No. 3	3·56	1·36
Bombay hydraulic-pressed cake... ...	3·67	1·70

The Bengal samples of castor cake are apparently richer in nitrogen and phosphoric acid than the Bombay samples :—

The following analysis taken from Collins' "Agricultural Chemistry" show the comparative values :—

	Average of Bombay Samples (11 analyses).	Average of Bengal and N.-W. Provinces Samples (3 analyses).
Water	8	7
Organic matter... ...	81	80
Nitrogen	3·75	6·9
$P_2 O_5$	1·6	2·9
Potash	1·9	2·6
Lime	1	·7

Karanj cake.

This cake is a non-edible residue left when oil is expressed from the seeds of *karanj* tree (Pongamia glabra). The cake is considered a valuable manure for irrigated crops. It is used in similar applications and otherwise in the same way as castor cake. The leaves and young twigs of the *karanj* tree also provide, especially in Madras, a useful manure for rice lands. They are trampled down into the soft mud before the rice seed is sown. *Karanj* seed yields about 20 per cent. of oil which is red-brown in colour and thick. Manufacture.

Dr. Voelcker gives the following analysis of *karanj* cake :— Analysis.

Water	12·19
* Organic matter	83·42
Total Phosphates	2·37
Alkaline Salts	1·98
Insoluble Silicious matter	·04
	100·00
Containing Nitrogen	3·54

Dr. Leather s analyses of ordinary commercial samples used at the Poona Farm give the following results :—

	Nitrogen. Per cent.	Phosphoric acid. Per cent.
Sample No. 1	3·35	·65
,, No. 2	3·94	......
,, No. 3	4·18	......
,, No. 4	3·30	·84

Value compared with castor cake.

The above analyses show that *karanj* cake is nearly as rich in potash as castor cake, but slightly poorer in the more important elements—nitrogen and phosphoric acid. Therefore as manure it is, perhaps, inferior to castor cake. This fact appears to be recognised by the sugar-cane cultivators of the Poona district. In 1896 the price of *karanj* cake was about 55 lbs. per rupee and between 1896 and 1898 it could generally be bought at Rs. 5 per ton cheaper than castor cake.

Mowra cake.

Mowra or *bassia* cake is made from the seeds of the *mowra* tree (Bassia latifolia). It is a non-edible cake, bitter to taste and, sometimes owing possibly to poisonous ingredients, has a harmful effect upon crops whilst young. It is largely made in the hydraulic press mills of Bombay. The seeds are crushed and subjected to the dry heat of steam before the oil is expressed. The oil is chiefly exported and is used for admixture in the sheep dips so extensively used in Europe. *Mowra* cake is by no means a concentrated manure. It contains only about double the amount of nitrogen which poudrette and farm-yard manure sometimes contain, and though moderately cheap in Bombay it will not pay to transport it far. The Bombay rate in 1896 was Rs. 18 per ton. The freight charges to Poona are Rs. 9 per ton. *Mowra* cake costing at Poona Rs. 27 per ton is, I think, dear compared with other more concentrated cakes.

Manufacture.

Value.

Analyses.

Dr. Leather's analyses of samples used at the Poona Farm give the following results :—

	Nitrogen. Per cent.	Phosphoric acid. Per cent.
Sample No. 1	2·58	·93
,, No. 2	2·69	...

Cotton seed and cotton seed cake.

In India cotton seed with a good deal of adhering lint is used as a general food for work and milch cattle, as much as 6 lb. per day being given in the daily ration. The seed contains a good deal of fibrous husk. Neither the husk nor the lint is digestible and probably cotton seed would be a dangerous food for farm animals if it did not also contain a good deal of oil which

has a softening and digestive effect. Cotton seed is comparatively cheap in cotton districts and in such districts, for instance as Surat, there are considerable areas growing garden crops under irrigation. Manure is scant and dear, and probably cotton seed might be found useful in supplementing the present manure supply. When the seed is used as manure its germinating power has to be destroyed. This can be done by crushing the seed under the stone of a chunam mill. I have proved cotton seed to be an effective and quick acting manure for sugar-cane. When cotton seed is kept long in bulk it gets more or less unsound. It deteriorates as a cattle food and can be bought cheap. The storage has not damaged it in any way for use as manure. It has probably increased the value for the purpose owing to dryage.

Probably could be used economically as manure in some districts.

The expression of oil from cotton seed is unknown to the Indian *rayat*. The reason, no doubt, is that the percentage of oil in cotton seed is much less than in other oil seeds and is also considerably less than in Egyptian or American cotton seed. On section the latter varieties show the oil cells much more distinctly than in Indian seed.

Oil is not pressed from cotton seed by the Indian *rayat*.

Indian cotton seed which has been stored for a considerable time and thus become inferior as cattle food was used at the Poona Farm as manure.

The following shows the analysis of two samples of cotton seed by the Agricultural Chemist, Government of India.

Analysis.

	Sample bought in Poona Bazar.	Sample of Seed from Surat Cotton.
Moisture	6·93	6·83
Oil	14·57	16·51
Albuminoids ...	11·34	12·54
Carbo Hydrates (diff.)	35·96	32·54
Woody Fibre ...	25·05	27·11
Mineral matter ...	6·15	4·47
	100·00	
Total Nitrogen ...	2·49	
P_2O_5	1·20	
Alkalies	2·18	
Lime	·95	
Sand	1·68	

A cake made from husked American or Egyptian cotton seed is largely used for cattle food in Europe. It is known as decorticated cotton cake and its manurial residue value is at least equal to that of any other food. The cake from husked ground-nut has about the same manurial value as the decorticated cotton cake. The oil from cotton seed has a pale yellow colour and resembles olive oil so much in taste and appearance that it is largely

The manufacture of American or Egyptian cotton seed cake.

employed as a substitute for or for adulterating olive oil. Before extracting the oil the seeds are cleaned to remove dirt, then the short fluff which adheres to the seed after ginning is removed by special machinery. The seeds are then partially crushed or hulled to remove the husks from the kernels. The husks are separated by sifting. The kernels are passed through heavy rollers and the meal is conveyed into steamers to be cooked. The steamers are iron vessels with false bottoms which allow steam to be introduced. The dry heat applied is sufficient to liberate the oil from the cells. The cooked meal is removed, placed in sacking, and compressed to take the form of a cake. The cake with the cloth round it is subjected to hydraulic pressure of 2,500 lbs. to 3,500 lbs. per square inch.

Indian cotton seed cake.

American cotton seed contains 28 per cent. of oil; the decorticated cake contains over 7 per cent. nitrogen. An undecorticated cotton seed cake experimentally manufactured from partially cleaned seed at a Bombay hydraulic press mill and used at the Poona Farm as manure was analysed by Dr. Leather and found to contain 3·14 per cent. of nitrogen and 1·26 per cent. of phosphoric acid. For sugar-cane it was found to be quick acting and more effective than equivalent applications of castor cake or *karanj* cake.

In the Bombay cotton districts cotton seed can usually be bought at about 60 lbs. per rupee.

Earth-nut or ground-nut cake.

Earth-nut or ground-nut cake is got from the seeds of Arachis hypogœa. The kernels of ground-nuts are extremely rich in oil and like all other leguminose seeds contain a large percentage of albuminoids. The cake residue left, when the oil is expressed, is a food extremely rich in nitrogenous matters and the manure from farm animals fed on it would have a [illegible] manurial value. It is when in sound condition too valuable as a cattle food to be directly used as manure, but the cake when kept long is apt to deteriorate. The oil left in the cake may turn rancid or the cake mould. The cake damaged in this way would be extremely valuable as manure.

A highly nitrogenous oil-cake.

Analysis

The following is an analysis of ground-nut kernels by Dr. Leather :—

Moisture	4·70
Oil	49·25
Albuminoids	29·09
Carbo Hydrates	13·21
Woody Fibre	1·65
Ash	2·10
	100·00
Total nitrogen	4·65
P_2O_5	·9

Assuming that the seed under pressure yielded 40 per cent. of oil, which is perhaps an underestimate, the residue cake from the above sample of seed would contain

Moisture	7·83
Oil	15·41
Albuminoids	48·48
Carbo Hydrates	22·02
Woody Fibre	2·75
Ash	3·50
	99·99
Containing Nitrogen	7·75
P_2O_5	1·5

Dr. Voelcker found that the cake made from properly cleaned ground-nut kernels contained 7·65 per cent. of nitrogen. The seed contains about ·9 per cent. P_2O_5.

Damaged ground-nut—niger-seed cake a cheap manure.

In the Bombay mills oil is seldom expressed from earth-nuts alone. The nuts are mixed with safflower seed in the porportion of 3 to 1 or with niger-seed in equal proportion. The ground-nut-niger cake is in considerable demand as food for milch and work cattle. The ground-nut-safflower cake is not so highly esteemed by natives as cattle food, and it is chiefly exported. Broken cake or damaged cake of this kind can often be bought up in quantity in Bombay at very cheap rates, *viz.*, Rs. 26 to Rs. 30 per ton, or say 75 to 80 lbs. per rupee. This mixed cake has been used with good effects for sugar-cane on the Poona Farm and samples analysed by Dr. Leather showed it to contain :—

	Nitrogen. Per cent.	Phosphoric acid. Per cent.
Sample No. 1	6·5	1·32
" " 2	6·29	1·27

Sesamum or *til* cake.

Too valuable as cattle food to be used as manure.

Sesamum or *til* cake, from the seeds of sesamum indicum is in great request as a suitable concentrated food for milch cattle, and is too valuable for this purpose to be used directly for manure. It is a rich yet easily digested food usually sold in the Poona district at 35 to 45 lbs. per rupee. The cake is made from three varieties of seed, white, grey and black. The

cake of the first is considered best, but the oil from the black variety is believed to be the most valuable. The seed contains about 37 per cent. of oil.

Analyses.

Dr. Voelcker gives the following analysis of the cake :—

Water	11·
Oil	13·01
* Albuminoid compounds	38·92
Carbo Hydrates and digestible fibre	22·12
Woody Fibre	4·70
Mineral matter and ash	13·22
* Containing Nitrogen	6·22
Containing Sand...	2·89

The following are analyses by Dr. Leather of sesamum cakes made from the three varieties of seed :—

	White seed.	Red seed.	Black seed.
Moisture	15·87	10·39	10·09
Oil	20·83	14·12	18·64
* Albuminoids	28·27	29·46	30·80
Carbo Hydrates ...	21·02	29·91	24·13
Woody Fibre	5·34	3·88	4·60
Ash	8·67	12·24	11·74
	100·00	100·00	100·00
* Containing Nitrogen...	4·02	5·81	4·93
P_2O_5	...	1·95	...
Sand	·59	3·72	2·14
Ca O	...	2·07	...
Alkalies	...	3·99	...

Niger-seed or *khurásni* cake.

A useful cattle food.

Niger-seed or *khurásni* cake got from the seeds of (Guizotia Abyssynica) is erroneously called *til* or *kála til* in the Deccan. The cake is largely fed to cattle, particularly to milch cattle. It commands in the Poona district a higher price than its chemical analysis would warrant. As a cattle food it is decidedly inferior to sesamum cake, yet it is generally sold at the same price, *viz.*, 35 to 45 lbs. per rupee.

Manufacture.

The following results were obtained on the Poona Government Farm in extracting oil from niger seed in the ordinary country *ghāni*. The weight of oil and oil-cake exceeds the weight of oil-seed, because water was added to the half crushed seed in order to give a degree of wetness necessary to consolidate the cake so that the oil separated properly.

Weight of oil-seed.	Weight of water added.	Total weight.	Weight of oil.	Weight of oil-cake.	Loss.	Percentage of oil to seed.	Percentage of cake to seed.
lbs.	lbs.	lbs.		lbs.	lbs.		
543	76	619		457	10	28	84·15

Analyses.

Dr. Leather gives the following analysis of niger-seeds:—

	Mixture of two samples.
Moisture	6·72
Oil	39·69
Albuminoids	19·47
Carbo Hydrates	14·02
Woody Fibre	13·65
Ash	6.45
	100·00
Nitrogen	3·13
Sand	2·42
Ca O	·813
$P_2 O_5$	1·67
$K_2 O$ } Alkalies	·75
$Na_2 O$ }	·72

Assuming that the above oil-seed yielded 30 per cent. of oil the resulting cake would have approximately the following analysis :—

Moisture	9·6
Oil	13·86
Albuminoids	27·81
Carbo Hydrates	20·03
Woody Fibre	19·5
Ash	9·21
	100·01
Containing Nitrogen	4·47
Sand	3·46
Ca O	1·16
$P_2 O_5$	2·39
$K_2 O$	1·07
$Na_2 O$	1·03

Coconut cake.

Cocoanut cake (*copra*) is extensively manufactured in the Bombay oil mills. The kernels which are extremely rich in oil are brought chiefly from the Malabar Coast in round packages enclosed by coarse sacking. The kernels are broken into two equal parts and sun-dried, and when they reach Bombay are comparatively free of moisture and have a tough leathery appearance. In this condition they are passed through pulping machines and are chopped up into fine pieces. The pulped material yields in the ordinary country *ghání* 58 to 64 per cent. of clear limpid oil which is purified by simple settling in tanks. The cake is worth in Bombay 45 lbs. per rupee, and is either used locally or exported to Káthiáwár in open boats and there used as food for milch buffaloes. The cake soon turns rancid and on this account there is always a quantity of damaged cake for sale in Bombay and can be bought at 80 to 100 lbs. per rupee. At this price cocoanut cake could be used economically as manure.

Manufacture.

Value.

Analysis.

The following is an analysis by Mr. S. H. Collins :—

Moisture	7·72
Oil	16·53
*Albuminoids	13·62
Carbo Hydrates	44·57
Woody Fibre	12·45
Ash	5·11
	100·00
*Containing Nitrogen	3·31
P_2O_5	1·14
Sand	·458
Ca O	·211
Alkalies	3·42

Safflower cake.

Safflower cake is got from the seeds of (Carthamus tinctorius)—*kardai* (Deccan), *kasambi* Gujarát. Two forms are cultivated in the Bombay Presidency. (*a*) The yellow flowered thorny variety of the Deccan grown only for its oil-seeds; (*b*) a less spiny or nearly spineless form with reddish orange flowers cultivated in Gujarát as a dye-plant and also for its seeds. It is probable that the seeds from the dye-plant give oil-cake generally poorer in quality than that from the seed-plants, because the removal of the petals for dye interferes with the full development of the seed. The unhusked seed of the dye-plant is popularly believed to yield 20 to 25 per cent. of oil. By actual test I got 13 per cent. from the seed of the Gujarát dye-plant and 21·6 per cent. from the seed of the Deccan seed-plant. The best cake is got from husked seed, but even this cake contains an appreciable percentage of husk. The husk is coarse and fibrous and an undue proportion

Manufacture.

makes the cake more or less unsuitable as cattle food. Safflower cake from properly husked seed is one of the very best and cheapest foods for cattle in the Deccan. It keeps free of mould and good for months, and therefore can be bought when cheap and stored. When cheap it sells at 80lbs. per rupee, and usually costs 60lbs. per rupee in the Poona district. The cake usually commercially known as *kardai* is not usually made from safflower seed alone. Ground-nut is generally mixed with it, also a small proportion of sesamum. The oil expressed is the sweet oil of the bazars. Safflower cake may therefore be of variable composition. This does not affect its price. Value.

The following are analyses by the Agricultural Chemist, Government of India, of a sample of safflower seeds and of two samples of safflower cake; the first made from partially decorticated safflower seed, the second bought in the Poona bazar under the name of safflower cake :— Analyses.

	Partially decorticated seed.	Poona Bazar.	
	Cake.	Cake.	Seed.
Moisture	8·49	12	7·49
Oil	9·80	3·78	31·84
*Albuminoids	32·75	16·91	13·31
Carbo Hydrates	21·19	41·48	18·66
Woody Fibre	20·17	19·40	26·31
†Ash	7·60	6·43	2·39
*Containing Nitrogen	5·24	4·92	......
$P_2 O_5$	......	1·25	......
†Containing Sand	4·	2·07	......
Ca O	......	·686	......
Alkalies	......	·876	......

The safflower cake possibly made as usual from safflower and ground-nut seeds has been used as manure for several crops for several years with remarkably good effect at the Poona Farm. Its effect on sugar-cane in 1895-96 was better than of any cake or any other manure tested. Safflower cake as manure for sugar-cane has proved itself cheap, effective and extremely quick acting. A valuable manure for sugar-cane.

Dr. Leather's analysis of some samples employed gave the following percentage of nitrogen and phosphoric acid :—

	Nitrogen. Per cent.	Phosphoric acid. Per cent.
Sample No. 1	6·85	2·08
Do. „ 2	5·32	......
Do. „ 3	5·65	......

The two latter samples were probably prepared from safflower seed only, the seed being fairly well decorticated.

AGRICULTURAL IMPLEMENTS.

Indigenous implements are generally suitable to the conditions of Indian Agriculture.

In this chapter the more important indigenous tillage implements known in the Bombay Presidency are illustrated and described. I have purposely excluded any reference to or description of agricultural implements which are not purely indigenous. I have done so because I believe that the implements in ordinary use are entirely suitable for the conditions of Indian agriculture. This statement may be objected to by other authorities, but if such is the case, I am afraid, I cannot change a deliberately expressed opinion. To those who are sceptical I can show in parts of the Presidency cultivation by means of indigenous tillage implements only, which in respect of neatness, thoroughness and profitableness cannot be excelled by the best gardeners or the best farmers in any other part of the world. That statement I deliberately make, and am quite prepared to substantiate. The hackneyed expression that an Indian plough merely scratches the surface is pure nonsense. There are ploughs and ploughs. The best of the indigenous kinds—the most effective at work—might with advantage be more widely known *in* the country and the same might be said of other indigenous implements, but there is certainly no need to go out of the country for the ordinary tillage implements which are required.

Reasons given fo the above conclusion.

The implements and tools required for a fair sized holding in India cost little more than the price of a single English iron turn-furrow plough. With cooly labour at 2 or 3 annas per day there is no room in this country for steam diggers, steam thrashing machines, winnowers, harvesting binders, grass mowers, horse rakes, crosskill clod crushers and the hundred and one other labour saving appliances which are absolutely necessary in those western countries where agricultural labourers are paid at high rates. The work which such machinery can do, can be done as well by cooly labour at a cheaper cost. I can get black soil hand-dug to a depth of a foot or more in the fair season cheaper and better than could be done by the best steam plough or steam digger in existence. Our indigenous tillage implements have one special advantage over the stronger and more expensive European implements. Their parts mostly consist of wood, and after rain as soon as the surface dries such implements can be used. Iron implements could not be used so soon because moist earth sticks much more tenaciously to iron than to wood. Delays in tillage or sowing early in the monsoon or, in fact, at any season owing to the cause mentioned would produce disastrous results. The full benefit of a good monsoon can only be obtained when the cultivator exerts himself to the fullest extent in preparing and sowing his fields in the breaks between heavy downpours of rain.

LIST AND ILLUSTRATED DESCRIPTION OF NATIVE AGRICULTURAL IMPLEMENTS—BOMBAY PRESIDENCY.

Gujarát *HAL* or *SÁNTI* (light Gujarát plough). Ill. 1.

Description.

This is a light plough. The stilt is one piece with the body, both being formed from a plank seldom more than 3 inches thick. The draft pole is mortised into this plank. Below the point of insertion the body of the plough is bevelled off to an edge which lessens the draft, the effect being the same as that of a coulter on an English plough. This cutting edge is carried down to where the shoe (a separate piece called the *chovra*) is mortised in at an obtuse angle to the body of the plough. The share (a short pointed piece of iron) is nailed to the shoe. The *chovra* soon wears out. Two ought to last a monsoon if taken care of. In dry weather when the soil gets hard they are very liable to break off at the neck.

The *hal* at work.

The *hal* is used for stirring the soil. It is used during the monsoon and while the soil is still moist. It is worked by two bullocks and goes 3 to 5 inches deep. The draft pole and neck yoke provide the means of draft in all ploughs and indigenous bullock power tillage implements. The neck yoke at its middle rests horizontally on the draft pole. In Gujarát implements the draft pole has several notches cut in the draft pole or strong pins inserted therein at the part where the neck yoke is attached to the draft pole by means of raw hide thongs. The notches or pins provide a means of securely tying the neck yoke to the draft pole so that it does not slip. At work several notches or pins are necessary because with big bullocks the neck yoke has to be tied further forward on the draft pole than with small; and the implements as made by the village carpenter are necessarily adapted for all sizes of cattle. In the Deccan and Karnátak ploughs and other bullock power tillage implements the neck yoke is attached to the draft pole and held in position by a double rope which passes generally with a double turn back round the body of the implement and again forward to the point of attachment. (*See illustration No. 5* of Karnátak light plough).

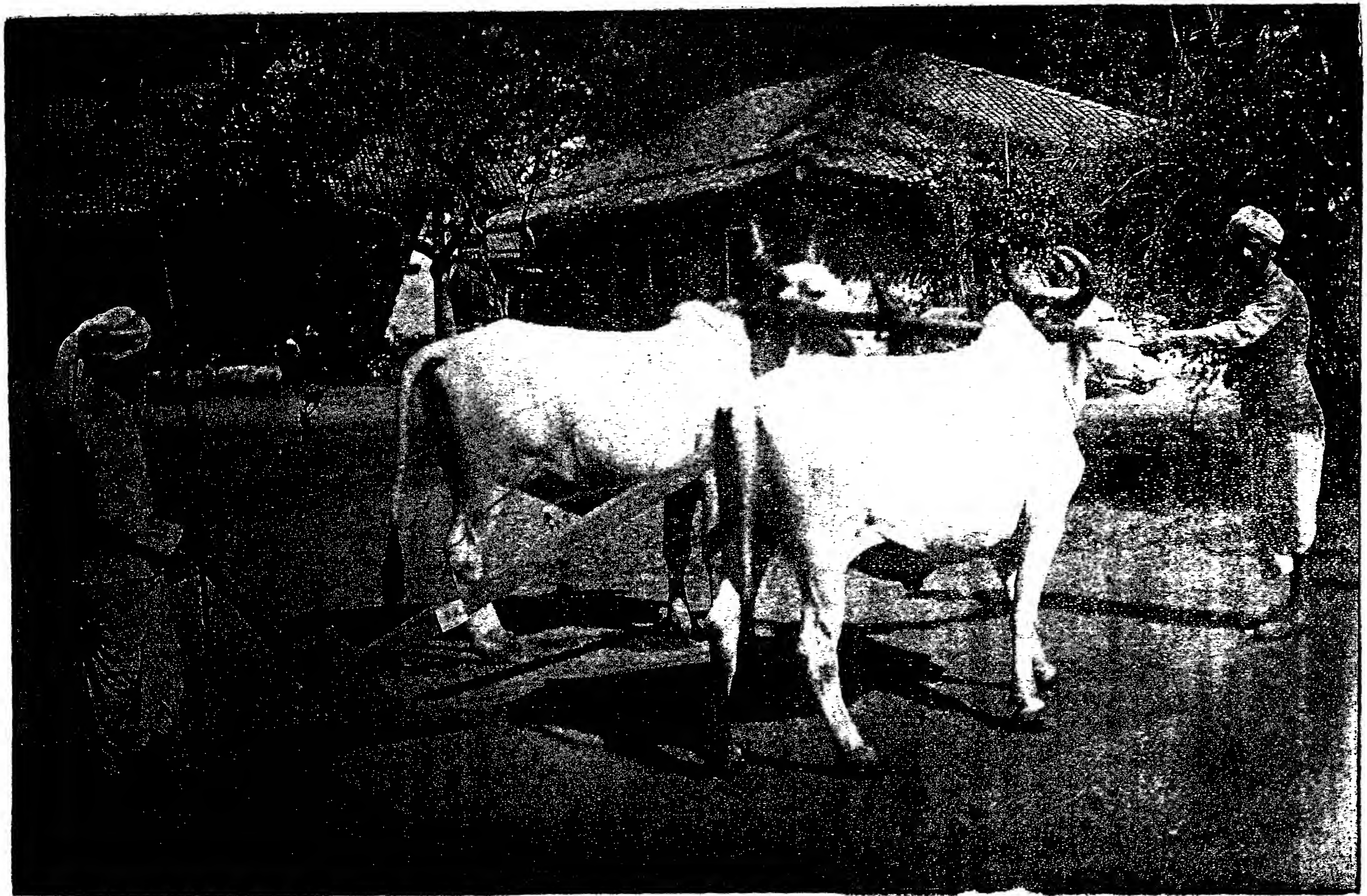
HAL (*Charotar* plough—Gujarát-Kaira District). Ill. 2.

Description.

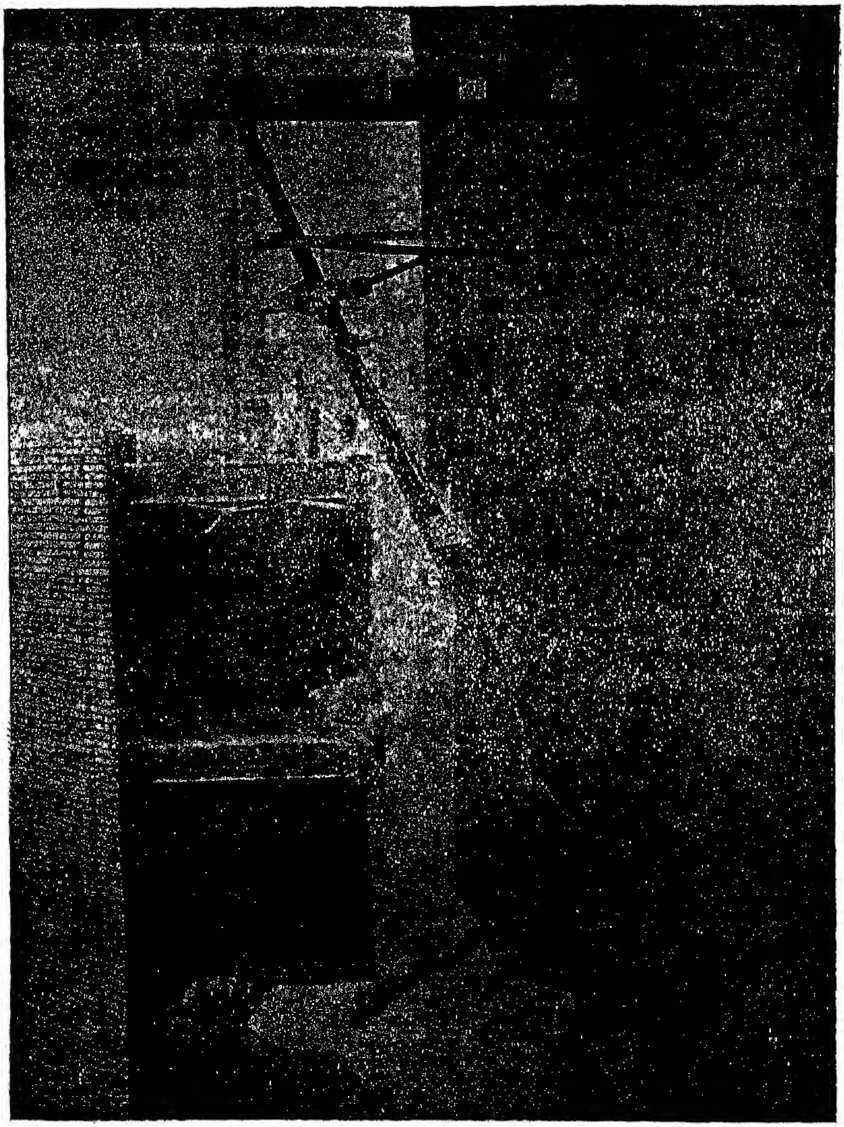
This is a more effective implement than the above, the construction being somewhat more substantial. The share, a sharp pointed iron, one inch square at the thick end, is 18 inches long. It is let into a groove along the whole length of the shoe and fits into a socket in the body of the plough where its pitch is adjusted by means of a wedge. It projects an inch or two beyond the point of the *chovra*. At work the stilt inclines in a slanting backward direction. Consequently, the handle is inserted into the stilt in front like the *hal*, and not behind as is usual in ploughs of other parts of the Presidency. It is more effective than the lighter *hal* or

Use.

sánti plough, and is used in the better villages of the *Charotar* by culti-



1.—Gujarat light plough (*hal*).



Gi ha of Kaira d

vators who keep good bullocks. The beam or pole is let into the body of the plough at an acute angle with the shoe and share ; consequently, the further forward the neck yoke is attached to the pole, the deeper the share penetrates the soil. This holds true of all ploughs. The nearer the attachment of the neck yoke to the working part of the plough the easier is the draft. This plough costs Rs. 5 to Rs. 6.

NÁGAL (heavy Gujarát plough.)

This is a still heavier plough and has no *chovra.* A spoon shaped iron share about 9 inches long and 3 inches wide is fixed permanently to the

body of the plough, and instead of the front of the body being bevelled off to a cutting edge, a piece of wood so fashioned is bolted on to the front of the body obviously with object of renewal when worn out. It works deeper than the *hal* and is drawn by four bullocks.

The average weight of the plough is 50 lbs., and the cost of it is about Rs. 6.

NÁGAL (Gujarát sugar-cane plough—Surat and Navsári Districts).

The *nágal* at work.

The share is not adjustable. It is fixed permanently to the shoe. The plough is drawn by three or four pairs of bullocks, and is only used in sugar-cane cultivation, either for stirring the land and forming ridges and furrows or for ploughing in whole canes. The whole canes are passed through a hole drilled through the body of the plough in a slanting backward direction and are thus imbedded in the furrow. At work a man sits on the beam and passes whole canes through the hole described. The canes are supplied by boys or women in attendance.

The cost of the plough is about Rs. 7 to Rs. 8.

NÁNGAR (Deccan plough—Khándesh district.) Ill. 3.

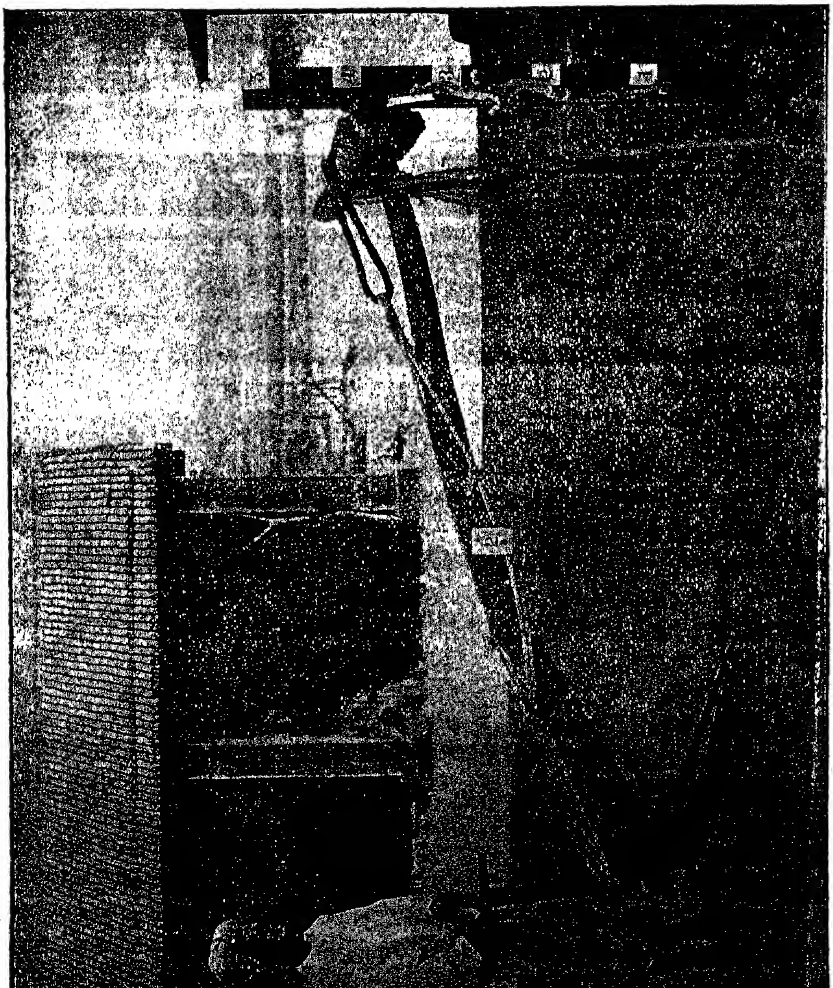
Description.

The body of the plough is a thick log of wood, shaped by the village carpenter, so that the lower end curves forward and forms the part that penetrates the soil. This penetrating part may be termed the shoe. It is hewn off to a point and forms an obtuse angle with the main block. The wood (usually *bábhul*) is one piece. The share, a square bar of iron flattened towards its penetrating point which is sharp, is about 3 feet long. It is laid along the top of the shoe, and its blunt end fits into a socket in the main block. At the point of the shoe it is secured by an iron ring driven home over both. Beyond the point of the shoe, the share juts out about 10 inches. A single short upright stilt with a short handle at right angle to it is fixed where the pole protrudes a little through the main block and the junctions of the stilt and of the pole to the body are braced by the draft ropes.

The Khándesh plough at work.

It is worked by one seldom by two pairs of oxen; it penetrates 7 or 8 inches. The depth is increased and the plough steadied at work by weighting the body with stones or by the ploughman throwing his weight on the body. The implement is probably the most effective in use for the deep tillage of the black soils of the wheat and cotton tracts. It is used in the fair season on land stocked with *kunda* (Ischæmum pilosum) and other deep rooted grasses. At this season, the soil is turned up into large clods, which weather down. The share penetrates the soil as a single tine of a grubber would, and either stirs the soil if it is in a friable condition, or dislodges compact lumps if the soil is dry and hard. The dislodgment is completed by the body of the plough.

The average weight of the plough is about 150 lbs. (yoke included). It costs about Rs. 6.

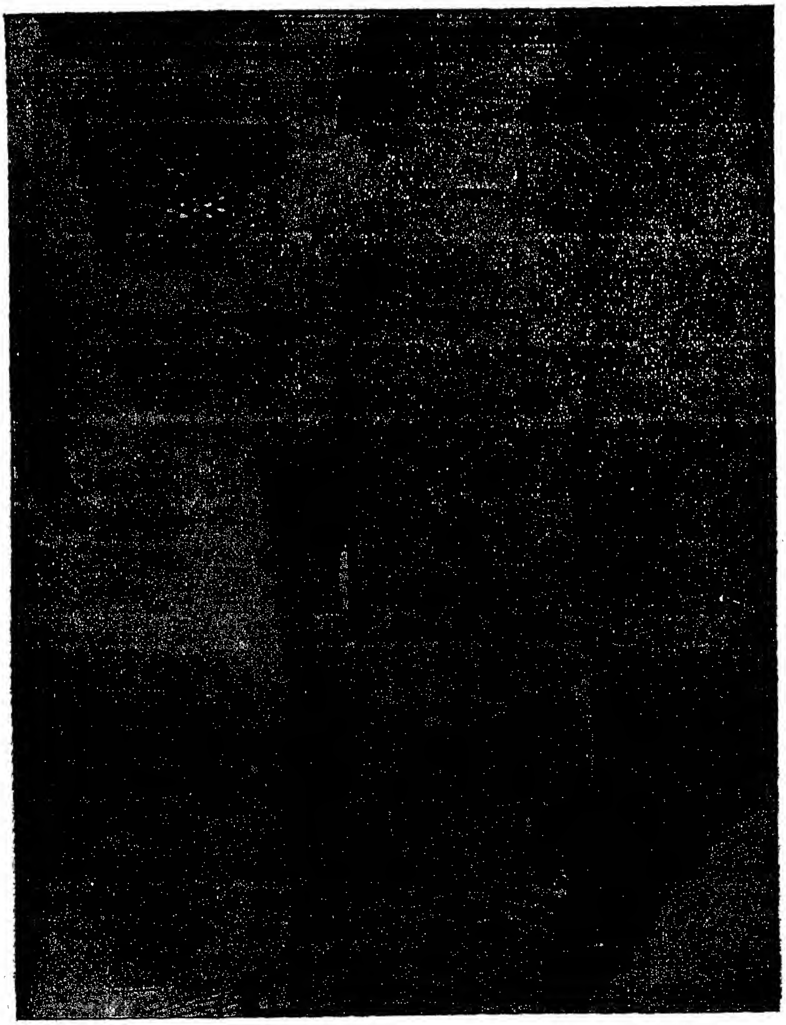


3.—Deccan plough (*nángar*) Khándesh district.

NÁNGAR (Deccan plough). Ill. 4.

The body of the plough is formed of *bábhul*, which when fashioned into proper shape combines, when at work, the effect of the main block as well as of the shoe of the Khándesh plough (*No. 3*). To form the body of the Deccan plough, a plank 3 feet long and 14 to 16 inches wide and 4 inches thick is required. The outside slab from a tree is most suitable, because the rounded side fits the bottom of the furrow better than a plank squarely sawn. The village carpenter with an axe hews the plank, so that it retains its original width at one end, but terminates in a blunt point at the

other. A square hole is chiselled through the plank in a slanting backward direction, so that the pole when inserted forms an acute angle with the body of the plough. The pole protrudes through the body two or three inches to furnish an attachment for the guiding lever or stilt. The stilt, the pole and



4.—Deccan plough (*nángar*).

the body are braced together by two or three turns of the draft ropes. The share is a flat iron bar hammered to a point at one end and curled into a socket at the other. The share is about 2 feet long. It is secured to the point of the body of the plough (beyond which it projects 8 inches) by a ring, whilst a stout piece of *bábhul* driven home into the socket is carried back and

secured where the pole is inserted. A longer share would answer the same purpose but would be more expensive. The object is to secure the share along the whole length of the shoe, so that the strain does not come on the weakest part, the point. A smaller plough of like construction would be called *nánguri*.

The Deccan plough at work.

The plough is worked by two to six pairs of oxen. The share penetrates the soil as a single tine of a grubber would, and either stirs the soil, if it is in a friable condition, or dislodges compact lumps if the soil is dry and hard. The dislodgment is completed by the body of the plough. A long clumsy heavy neck yoke is used for the pair of bullocks next the plough where three or more pairs are yoked. (*See illustration.*) This admits of the plough being turned at the end of each furrow with freedom. Moreover, the draft ropes of the leading pairs of bullocks are not likely to be entangled in the legs of the pairs yoked to the plough as the team is turned at the end of each furrow.

The approximate weight of the plough is 160 lbs. (neck yoke included), and it costs about Rs. 6 to Rs. 10.

NEGALU (Karnátak heavy plough).

Description.

The construction is practically the same as that of the Khándesh plough excepting the share, which is an iron bar 3 to 4 inches wide and weighs about 12 lbs. It is adjusted like that of the Khándesh *nángar*. Its length about 20 inches enables the plough to take a good hold of the soil and steadies it at work.

Karnátak heavy plough at work.

This plough is used only in the heavy black soil cotton tracts. It requires three to six pairs of bullocks to do effective work when the soil is baked and dry. It works deep enough to uproot deep rooted grasses. Black soil is deeply ploughed in the fair season when the grasses get well established, but when the field has become very weedy, this plough is not able to work, and the field has to be hand-dug.

The weight of the plough is approximately 150 lbs. Its cost is from Rs. 8 to Rs. 12.

RANTI (Karnátak light plough). Ill. 5.

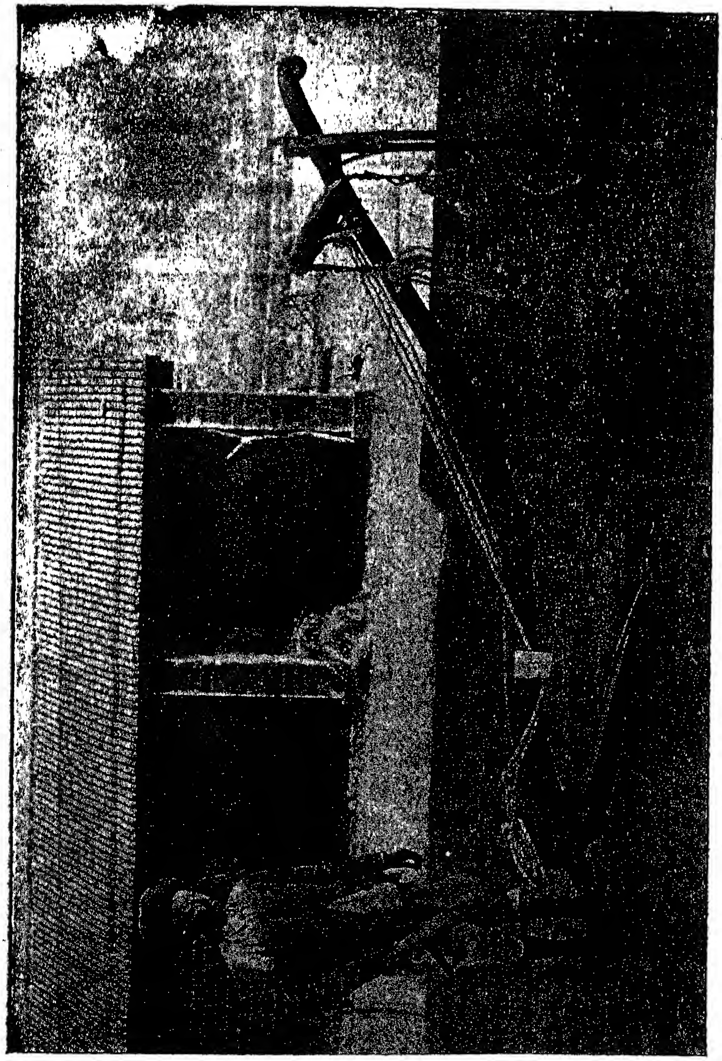
Description.

The construction of the plough resembles the *negalu* on a much smaller scale. The share, a light pointed piece of iron, does not project beyond the point of the shoe. It is laid along the top of the shoe and two stout staples secure it thereto for a length of 1 foot or 14 inches.

Karnátak light plough at work.

It is drawn by one pair of bullocks and is used on light soils, and only after the soil is moist after rain. It penetrates to a depth of 3 to 6 inches.

Its approximate weight is 80 lbs. (yoke included). It costs from Rs. 5 to Rs. 6.



5.—Karnátak light plough (*ranti*).

NÁNGAR (Konkan plough).

This plough is very similar to the *ranti* but the share differs. It resembles that of the Deccan *nángar*, but is much smaller and lighter. It is secured and adjusted like the share of the Deccan *nángar*, but it projects only slightly beyond the point of the shoe. This plough is usually made of teak and *khair* (Acacia catechu). Description.

In the rice fields the plough is drawn by two buffaloes, and either there or for dry crop cultivation can only be used when the soil is moist. Konkan plough at work.

The approximate weight of the plough and neck yoke is 40 lbs. and its cost is about Rs. 5.

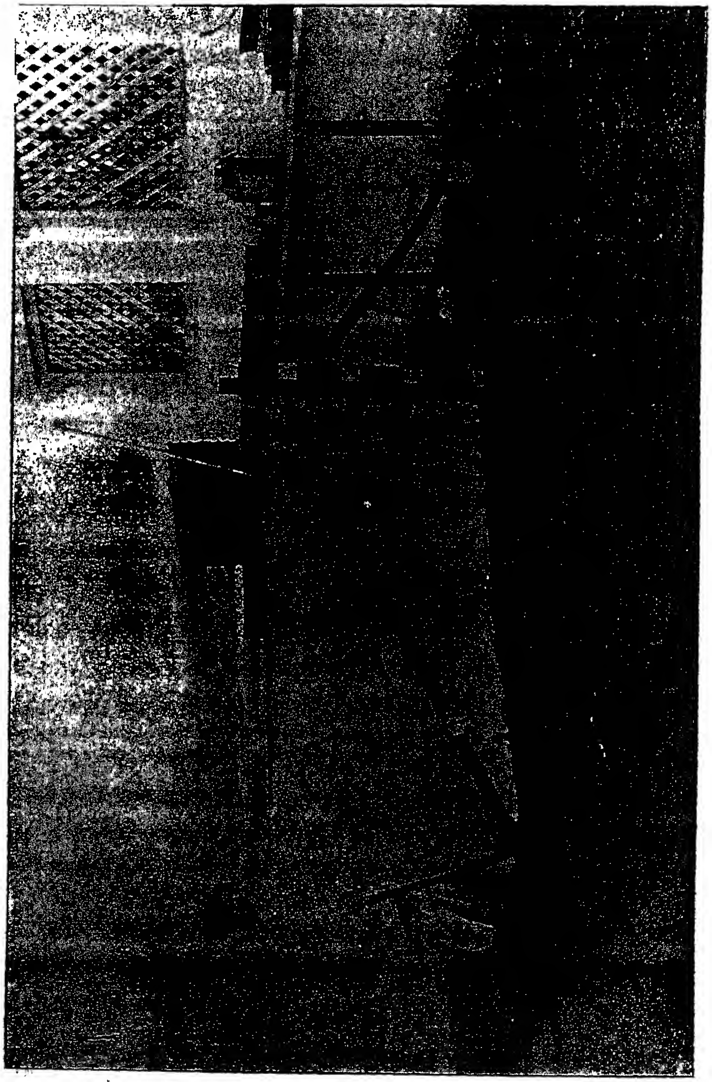
NÁNGAR (Konkan light plough). Ill. 6. No. 4.

Description.

This is made of the same wood as the heavier plough and excepting size is identical in construction.

Konkan light plough at work.

It is drawn by one pair of oxen or buffaloes. It is used to work up the rice fields after heavy rain has reduced the soil to the consistency of mud and even when the fields are covered with water 4 inches and more deep. It is also used for the hill cultivation of the coarse hill millets when the gradient is not too steep.



6.—Konkan light plough (*nángar*).

The approximate weight of the plough is 20 lbs. and its cost is about Rs. 3.

KUDÁVNA (hand plough, used in the hill districts of the Presidency). Ill. 6 No. 5.

It is apparently the original of the Indian plough; sometimes the handle is 6 feet long. All that is needed to convert the *kudávna* into the plough is to make it larger, add a stilt and put on a yoke.

The *kudávna* at work.

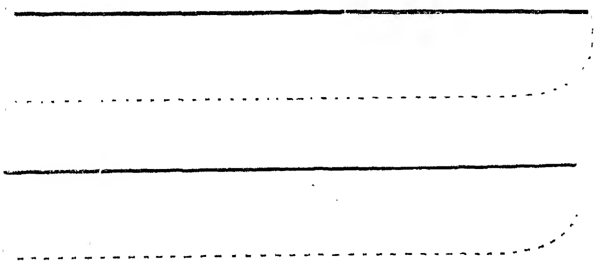
This hand plough is used by cultivators in hill districts where the ordinary plough cannot work to stir steep hill land for the cultivation of the coarse hill millets. It is drawn by hand by means of the cross handle at the end of the pole.

It costs Ans. 12 to Re. 1.

PHAN (a two or three pronged implement).

The *phan* at work.

It corresponds in construction to a very heavy drill with the seed bowl and seed tubes removed. It is used as a substitute for the plough. The implement works like a grubber uprooting weeds and stirring the soil to a considerable depth if weighted down with a heavy stone and drawn by 4 bullocks. The tines are tipped with iron shares which are nailed on. In two tined implements the tines are about three feet apart and at work the tracks made by the tines overlap the previous tracks. The tracks made by the tines in one direction are shown below by straight lines, in the back journey by dotted lines.



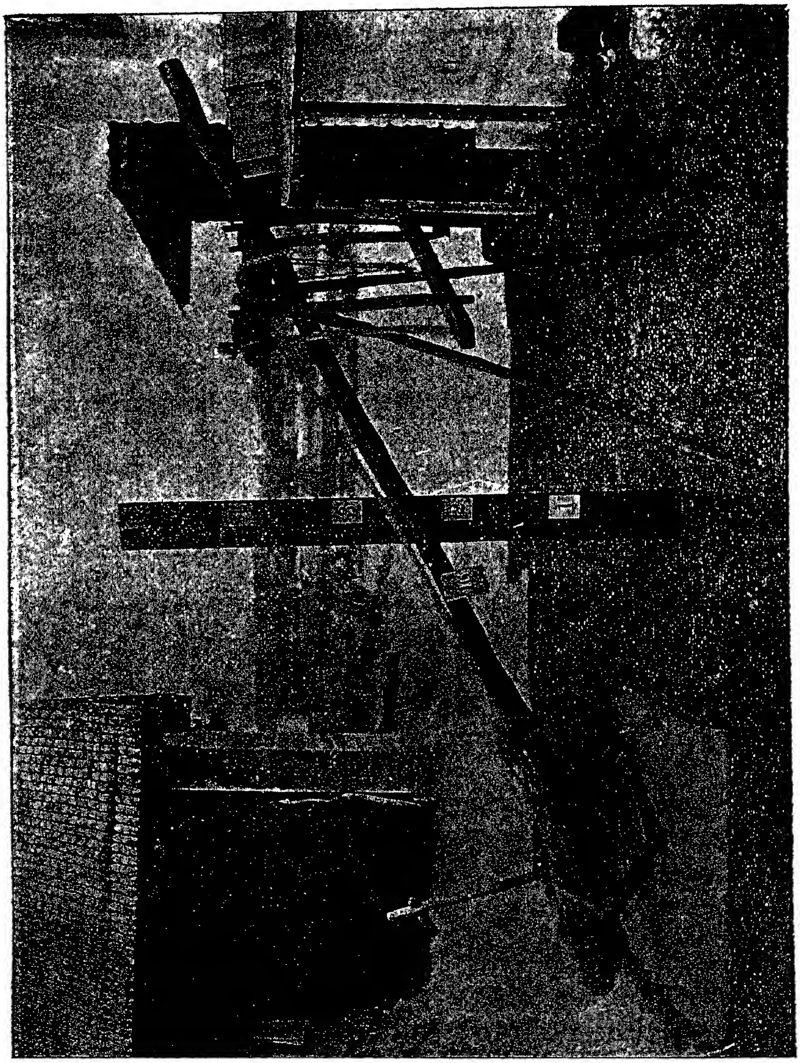
It is worked similarly across the field after the whole field is gone over lengthwise.

THE HEAVY HARROW OR SCARIFIER—*KARAP, KARAB, RÁMP*—Gujarát; *VAKHAR, AUT, KULAV, PHARÁT*—Deccan; *KUNTI*—Karnátak. Ills. 7 & 8.

Description.

Harrows are all of one pattern. The part that does effective work in loosening the soil and eradicating weeds consists of an iron blade of varying length and shape. Sometimes the blade is quite straight, often it is slightly curved like a sword. It is usually three feet or less in length and from $2\frac{1}{2}$ to 4 inches broad with its cutting edge sharper than the other. Each end is turned up 2 inches and hammered square or round. This adapts it to be fitted into two stout wooden stays or in Gujarát into two iron tubes. In the

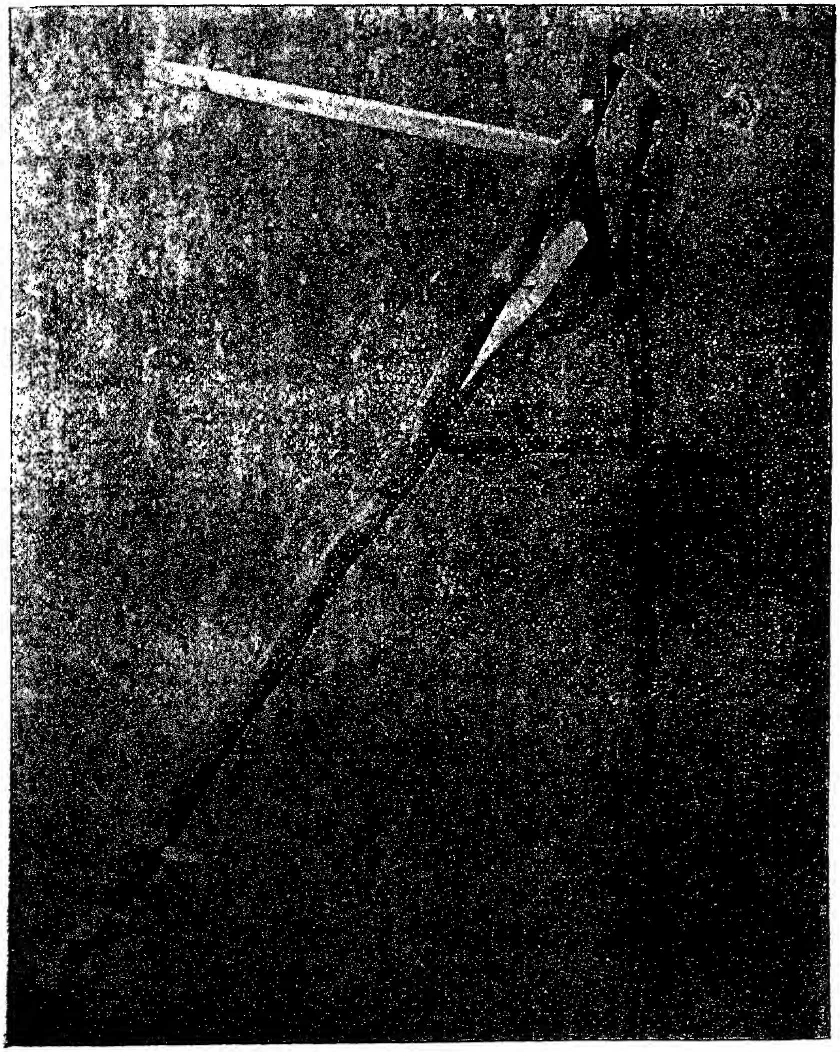
case of wooden stays the point of each is protected by an iron ring which guards the point of the stays from wear and holds the blade in position. At work the blade cannot get out of position. The resistance of the soil forces the ends of the blade more securely into their attachments. The



7.—Deccan scarifier or harrow (*vakhar*).

blade, not being permanently fixed, can easily be removed and carried home at night by the owner. The other parts of the harrow are not so likely to be stolen. The stays connect the blade with the horizontal beam which forms the head-piece of the harrow. The stays or prongs are pitched in a forward direction and as the blade passes through the soil at some

distance below the surface, it presents its cutting edge, so that the weeds are freely cut and the soil moved with a minimum degree of draft. To complete the harrow a draft pole, draft ropes and neck yoke are required; also a stilt or handle to guide it. The stilt rises with a backward inclination from the beam; consequently by using it as a lever the penetration of the imple-



8.—Gujarát scarifier or harrow (*karab*).

ment is increased. That also is attained by the driver standing on the beam or by weighting it with a stone. A rude platform is made for the purpose. Where the tough *tivas* (Ougenia dalbergioides) is used the beam is made of a piece of timber steamed or sawn and split for half its length. The split halves are forked out; further splitting is prevented by a nut and

bolt or a band of hoop iron passed round at the point where the splitting stops. Where *bábhul* and other kinds of wood are used the beam is of two pieces.

The heavy harrow at work.

These harrows or scarifiers are used extensively during the hot weather as a substitute for the plough, and also to follow the plough to prepare the seed bed. At work the wooden head-piece passes over the surface of the ground and acts as a very effective clod crusher, whilst the blade working below the surface acts as a scarifier. It is customary to use first a heavy harrow drawn by four bullocks, and then to harrow the land by a lighter implement drawn by one pair. The heavier kinds are used to work down the clods turned up by the plough. The lighter scarifiers are used after the seed is sown by the drill to level the surface and cover the seed ; frequently the stays and blade are removed and the head-piece is only used for the latter purpose.

These harrows cost from Rs. 4 to Rs. 8 according to size and weight.

DÁNTÁL (Gujarát harrow). Ill. 9.

Description.

This is the nearest likeness to the tined harrow of England. The implement is essentially a harrow. Its head-piece is made of a stout piece of *bábhul* about 5 or 6 inches square and 3½ feet long. Into this at a distance apart of 6 inches are fitted stout wooden tines or teeth. These teeth are 1½ to 2 inches square at the thick end, and are a foot long. Each tapers to a sharp point, which is shod with iron. They are set obliquely in the head-piece of the rake, so that at work the points are pitched forward, and the tines pass easily through the soil and do not drag weeds. A draft pole and guiding stilt fitted like those of the harrow complete the implement.

The *dántal* at work.

The implement is drawn by two bullocks and works across the rows of young crop for the double purpose of thinning the rows and weeding. The notches on the teeth allow weeds as they are raised to the surface and lumps of earth to pass between the teeth ; so that such material is not dragged by the implement.

Kodra fields are harrowed with this implement one or two days after sowing and before the grain has sprouted. The *dántál* works across the rows made by the seed drill. The *dántál* is also used in harrowing muddy rice beds before planting.

The harrow costs Rs. 3.

GHÁNIO (Gujarát harrow.)

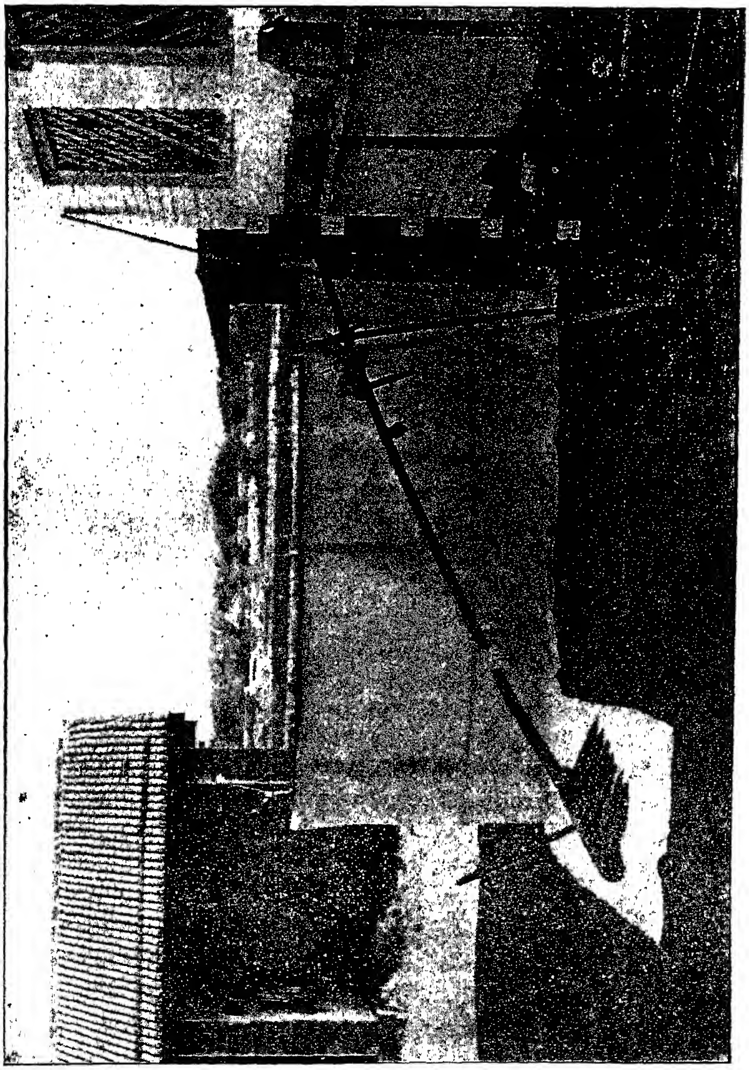
The construction is similar to the above harrow, but a short tooth and a long tooth alternate with each other. The tines are not shod with iron.

The *ghanio* at work.

The harrow is used in those rice fields where the practice is to sow the seed and not to transplant the seedlings. It works in fields covered with

water. The long *teeth* grub up the weeds, whilst the short ones lay them down in the soft mud. The object is to weaken the weeds or to eradicate them before the seed is sown.

It costs Rs. 2 to Rs. 3.



9.—Gujarát harrow (*dántál.*)

SAMÁR (roller and clod crusher of Gujarát.)

It is a plank of *ráyan* (Mimusops elangi) or *saunda* (Prosopis spicigera) wood 8 feet long, one foot broad and three inches thick. The traces are attached to rings bolted to the front edge. The driver standing upon the *samár* adds his weight to increase the effective power of the implement. Description.

The *samar* at work.

It is drawn traversely over ploughed land to crush clods and to level the surface; sometimes a brush harrow of branch wood is attached to the *samár* and dragged with it. The *samár* is occasionally used to cover seeds sown. It is useful particularly in levelling the surface of a field intended to be lined out for tobacco seedlings, or a field intended to be laid out into beds for irrigation. It is drawn by one pair of bullocks.

The approximate weight of a *samár* is 60 lbs. and its cost is about Rs. 2.

KEN (Deccan leveller.) Ill. 10. No. 10.

Description.

The *ken* of the Deccan is a rudely constructed implement. It is made of a *bábhul* plank, which works on edge. The plank is not straight. It takes the form of an elbow. One wing forms with the other an obtuse angle and the earth or clods collect against the concave surface. Holes are bored through each wing, and in these long shafts are inserted and secured. These meet at the point where the neck yoke is attached and form a draft pole for a pair of bullocks.

Use.

It is used also for levelling and for collecting earth for embankments of rice fields.

Its approximate weight is 45 lbs. and its cost is about Re. 1-8 to Rs. 2-8.

PETARA (leveller) of the Konkan and the Ghát districts of the Deccan. Ill. 10, No. 11.

Description.

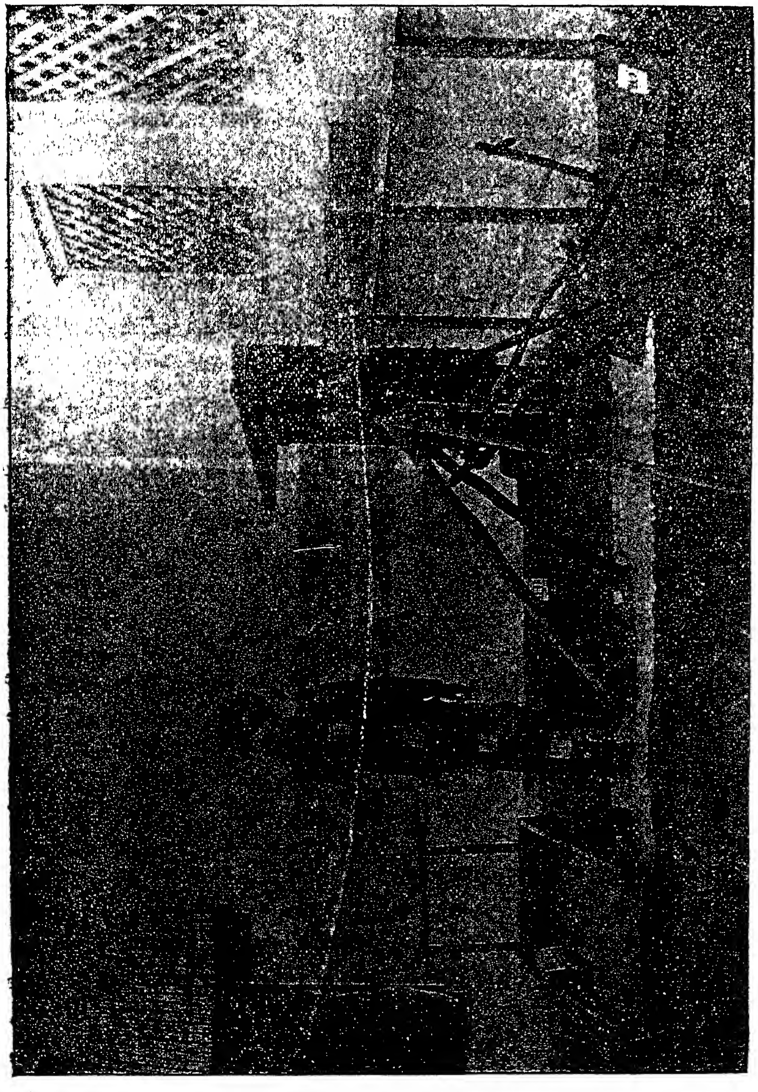
The *petára* is also a leveller. It takes the form of a scoop, rudely constructed but well calculated to do its work efficiently. The collecting lip is a hardwood plank bevelled off to a thin edge on one side, but $2\frac{1}{2}$ inches thick on the other. Into the thicker upper edge is mortised a stout handle which rises to a height of $2\frac{1}{2}$ feet. This with two other stays, one on either side, and a cross head-piece form a stout frame work which gives support to a series of bamboo slips ranged one above the other. These are laced together and bent to form a concave sloping surface, against which the earth is heaped as it accumulates. The handle rising above the level of the scoop may be used to lever the collecting lip into the ground or to tilt the implement when loaded. The collecting lip must be raised clear of the ground as soon as sufficient material has collected. This is managed in a very ingenious manner. The plank which forms the collecting lip terminates at each end in two axle-like projections. These give attachment to the pole, which is split out for half its length and forked out. The end of each fork has a hole drilled through it large enough to admit the axle ends of the collecting beam. The scoop can thus freely turn inside the spread of the two forked ends of the draft pole.

It is extensively used in levelling rice lands and to draw the clods and earth necessary to repair and make embankments in rice fields.

It costs about Re. 1 to Rs. 2.

CHEN (leveller of Gujarát—Kaira District.) Ill. 10, No. 12.

This consists of a platform $3\frac{1}{2}$ feet long and $2\frac{1}{2}$ feet wide, which is boxed Description.
in along each side and behind by side and end pieces 4 inches high. This



10.—Deccan leveller (*ken*) No. 10.
Konkan ,, (*petára*) No. 11.
Gujarát ,, (*chen*) No. 12.

platform is carried on an axle working in two trolly-like wooden wheels about a foot in diameter. The platform is so balanced that its anterior end by its own gravity rests on the ground. The collecting lip shod with sheet iron has

its power of collection increased by the draft strain, which is carried by ropes from two hooks in the bed of the *chen* to the neck yoke of the bullocks. Two stilts 2 feet long rise behind the axle from the bed of the implement, one on either side. These with a cross head-piece form a handle, which can be used to lever the collecting lip against the surface of the ground, or when sufficient material has been collected to raise the lip from the ground, and balance the load, so that it can be conveyed to any desired point. The *chen* is made of *bábhul* or other hardwood.

Use. It is used in rice fields for carrying soil to fill inequalities of the surface, which must be made perfectly flat for irrigation.

It costs about Rs. 4 or Rs. 5.

ALVAT (plank harrow or smaller clod crusher, used in the Konkan and in the Ghát districts of the Deccan).

Description. It is a plank of considerable length, worked on edge. It is drawn by a pole inserted through a hole made in the middle of the plank. When the point of the pole is raised to the height of the neck yoke of the bullocks, the lower edge of the plank is inclined forward.

Use. The chief use of the *alvat* is to follow the plough prior to transplantation of rice to level the mud bed to receive the seedlings. When worked in soft mud, it fills up hollows, and levels inequalities of surface precisely in the same manner as a mason's straight edge is made to level a concrete floor, whilst the cement is in a gruelly condition.

The weight of the implement is 26 lbs. and its price is Rs. 2.

PHALI or *MAING* (large clod crusher).

Description. The implement is used in the Konkan and the Ghát districts of the Deccan. It is a heavy log of wood, sometimes 20 feet long, fitted with a pole as well as a stilt.

Use. It is drawn often by four bullocks to crush clods and often after *rabi* seed has been sown to press the land so that moisture may be conserved.

It costs Rs. 2 or so.

GISALI (Gujarát tobacco-liner).

Description. This has a handle and head-piece like a large rake. The head-piece is about $4\frac{1}{2}$ feet long and has four iron or wooden tines or teeth about 5″ to 6″ long and placed equi-distant. This hand implement is drawn lengthwise and then across the field and marks out the land ready for transplantation into exact squares. Where the longitudinal and transverse lines cross each other seedlings are planted. When first drawn across a field four lines are

marked and subsequently only three new lines, because to ensure exactness one tooth is guided exactly along the outside line of those previously made.

This is used to line out the field to secure regularity in planting out tobacco, chillies and brinjals (egg plant). Use.

The *gisali* costs As. 12 to Re. 1.

DÁTÁLE (hand rake used in the Konkan and the Ghát districts of the Deccan).

The head-piece and teeth are of teak with a bamboo handle. The handle is generally over 12 feet long; sometimes 20 feet. The teeth are rather wide apart and 4 or 5 in number. Description.

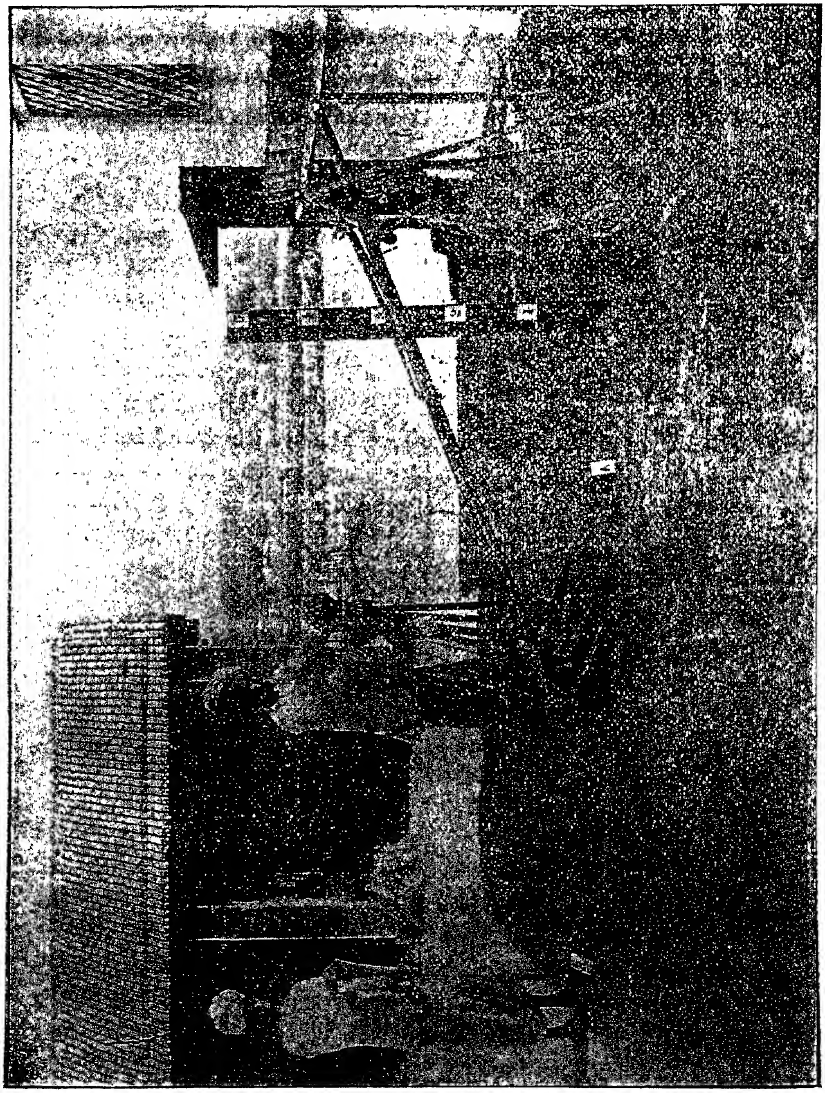
This is used to level the seed bed in rice cultivation. The rice seedlings are raised on a seed bed, whereon loppings of trees and brushwood, cowdung, leaves, grass, &c. are carefully laid and burned. The burnt material (called *ráb*) is left till the seed has been sown and with the seed is ploughed or harrowed in. The rake is then used to level the seed bed and its length of handle is needed to prevent the necessity of going on the land. Sometimes the seed is raked in after the seed bed has been lightly hand-dug with a pick, the plough and harrow not being used. The rake costs 8 to 12 annas. Use.

SEED DRILLS.

Charár—Gujarát	Four-coulter seed drill. Ill. 11.	
Pábhar—Deccan		
Kurigi—Karnátak		
Tarfin—Gujarát	Three-coulter seed drill. Ill. 12.	
Tiphan—Deccan		
Faidko—Gujarát	Two-coulter seed drill. Ill. 13.	
Moghad—Deccan		
Dusse—Deccan		
Hatti-kurigi—Karnátak		

A seed drill essentially consists of a stout piece of *bábhul*, which, like the head-piece of the harrow, gives support or attachment to all other parts. The draft pole and guiding stilt are secured in like manner to the harrow. Two, three or four coulters, as the case may be, are set obliquely in the *bábhul* head-piece. These are simply stout wooden prongs or tines. They are shod or tipped with iron. The distance between coulters varies. A round hole is drilled through each coulter half way between its points and its insertion into the head-piece. Into each of these holes, a bamboo tube is inserted. These tubes as they rise incline towards each other and meet about 3 feet from the ground to support the seed bowl, which is usually made of teak, sometimes of soft wood like mango. The bowl has as many perforations as there are tubes, and each tube is so adjusted to each perforation that a Description.

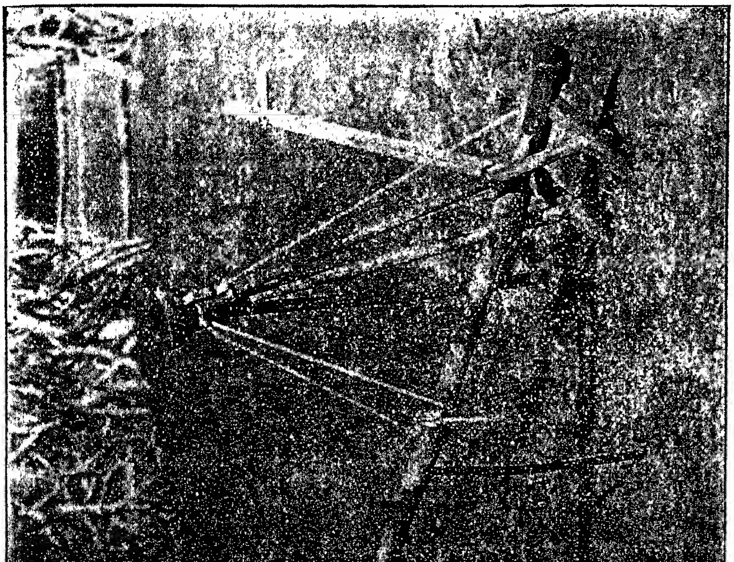
communication is made between the bowl and each tube. The seed is fed into the bowl and experience regulates the seed rate. The different parts of the seed drill are held together by ropes strained in different directions.



11.—Deccan four-coulter seed drill (*pábhar*).
(A) Seed bowl shown separately.
(B) Separate seed tube for sowing subordinate crops.

Seed drills are all much alike in pattern. The character of the soil determines to some extent the number of coulters. In those districts where heavy black soil predominates, the two-coulter drill is more or less common. In medium land the three-coulter drill is ordinarily used. In the light soils of the Deccan and the sandy soils of Ahmedabad, the four-coulter drill is the one most used for ordinary crops ; but in almost every district all three are met

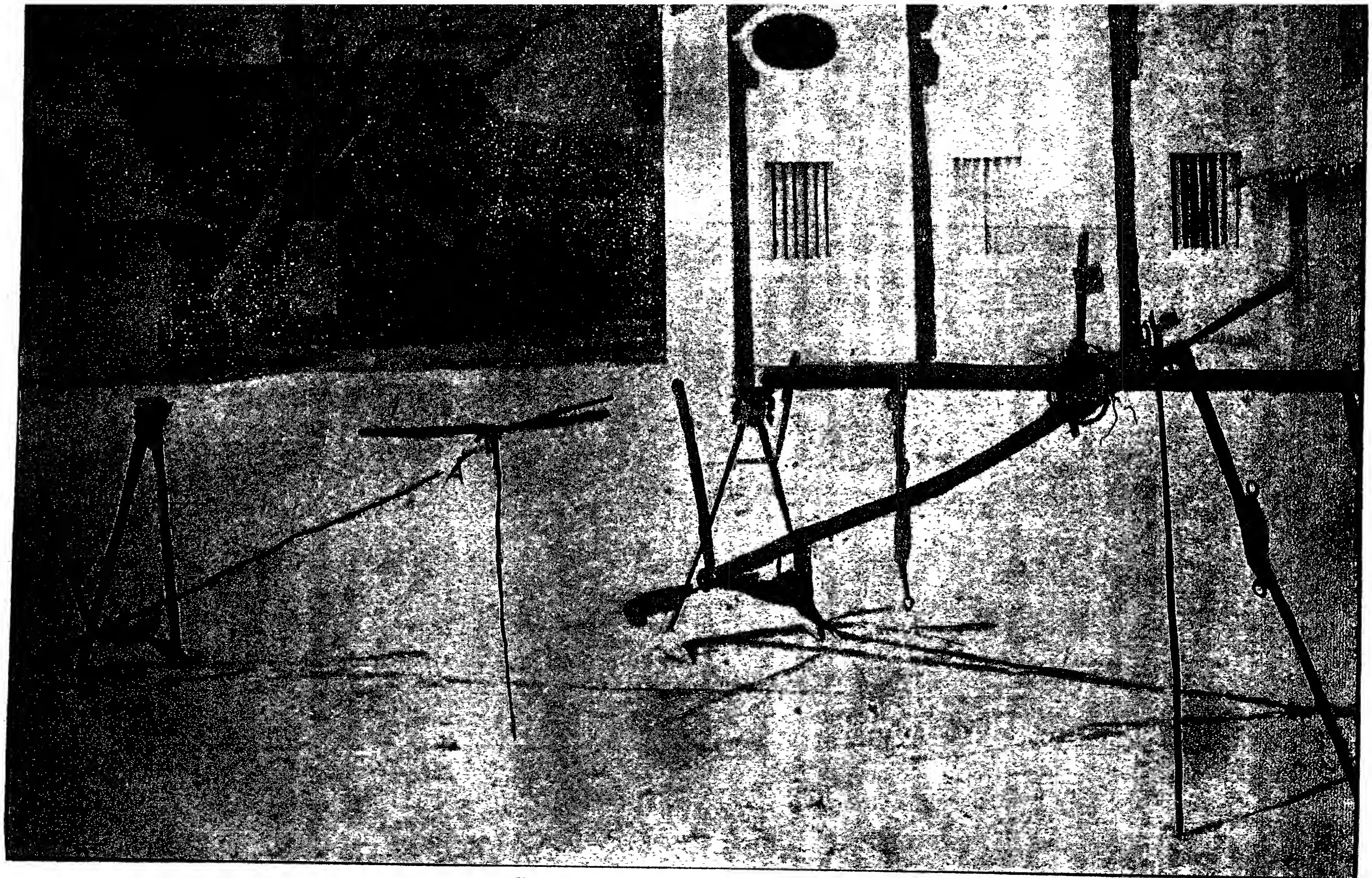
with. A light description of drill is generally used for *kharif* sowing, and a much heavier one in the *rabi* season. It is imperative that the seed of winter crops should be dropped into a deep furrow to reach moisture and secure even germination. A six-coulter drill for rice is used in parts of the Southern Marátha country. It works easily in the soft mud in which rice is sown. Six coulters would cause heavy draft in ordinary dry crop land.



12.—Gujarát three-coulter seed drill (*tarfin*).

The seed drill at work.

An expert cultivator guides his bullocks chiefly by voice. With one hand he guides the seed drill, with the other feeds the seed into the seed bowl, whence it is conveyed through the bamboo tubes to the ground. But two men generally are employed, one guides the bullocks, the other sows. At



13.—Gujarát two-coulter seed drills (*faidko*).
(A) For hand power.

work the coulters each cut a deep furrow. The seed drops into this track. The soil moved by the coulter necessarily falls back in part into these furrows, but the seed is meantime deposited so that in the act of sowing it is partly covered. A light harrow following completes the covering. The three or four-coulter drill without the seed bowl and tubes is used in Gujarát in giving the last hoeing to *bájri*, the tines working between the rows. It is also employed in preparing the land for sowing, when it does the work of a light grubber.

The sowing of subordinate row crops.

When the cultivator desires to sow subordinate rows of crop with his principal crop he may use the seed drill for the purpose. When a three-coulter drill is used twelve rows (or some multiple of three) of principal crop alternate with three rows of subordinate crop. Similarly with a two or four-coulter drill, the number of rows of principal crop are always a multiple of the number of alternate rows of subordinate crop. The more common method of sowing the seed of a subordinate crop is, however, through a separate seed tube with a funnel shaped mouth attached to the drill by means of a rope about 4 feet long, (*See B in illustration 11*) and guided by a woman along the track made by one of the coulters of the drill. If the cultivator wishes to sow one row of subordinate crop alternately with three rows of principal crop, he uses the four-coulter drill. In going in one direction the outside tube is stopped by plugging the corresponding hole in the seed bowl to prevent the seed of the principal crop passing through that particular seed tube and the seed of the subordinate crop is sown in the row. In the return journey the tube on the opposite side of the seed drill is stopped and the seed of the subordinate crop sown in the row. The attachment of the separate seed tube to the drill has therefore to be untied at each turn of the drill. A hook is used as means of attachment; and consequently there is no loss of time in tying and untying. Sometimes the seed of the principal and subordinate crops are mixed before sowing, in which case each row will contain a mixed crop. Sometimes none of the seed tubes of the drill are stopped, in which case the seed of the subordinate crop is deposited in one of the rows already sown with principal crop. Every fourth row (or as may be otherwise arranged) will contain mixed crop.

TWO-COULTER COTTON DRILL—*HATTI KURIGI*—Karnátak; *DUSSE*—Khándesh district.

Two rowed drill for cotton.

This drill has coulters 16 to 18 inches apart and is used for cotton. The drill forms furrows into which cotton seed is dropped through bamboo tubes, which are attached to the main drill by ropes and are guided along the furrows about 4 feet behind the drill and fed with seed each by one woman. These tubes have funnel shaped mouths, (*See illustration 11*) so hat the seed is easily dropped into the tube. The end, which is guided along

the furrow, is shod with iron and fitted with a shoe, which slips along the surface and thus prevents the seed being deposited deeper than about 3 inches. The drill is used for sowing cotton only, but can be used as a wide two-coulter drill for other crops, the seed tube and seed cup being fixed as in the ordinary seed drill. In Gujarát cotton seed is drilled through a seed bowl and seed tubes, like the seed of other crops, but the perforations in the seed bowl and the tubes of the seed drill are specially larger. This is necessary, because cotton seed sticks together even though well prepared for sowing.

LIGHT BULLOCK HOE—*KARABDI*, *KARPI*, *HATHIA*, *RÁMPDI*—Gujarát; *RAKHIA*—Deccan; *BALESÁL-KUNTI*—Karnátak. Ill. 14.

Description.

It is a small implement of similar construction to No. 11 with a blade varying from 7″ to 15″ wide.

Use.

It is used exclusively to hoe between the rows of standing crops. An implement with wide blade is used in cotton or such crops as are sown 18 inches or more between the rows. The *karabdi* of Gujarát like the *kolpa* of the Deccan is worked in pairs, drawn by a pair of bullocks and guided by two men.

The implement costs Re. 1-8 to Rs. 2.

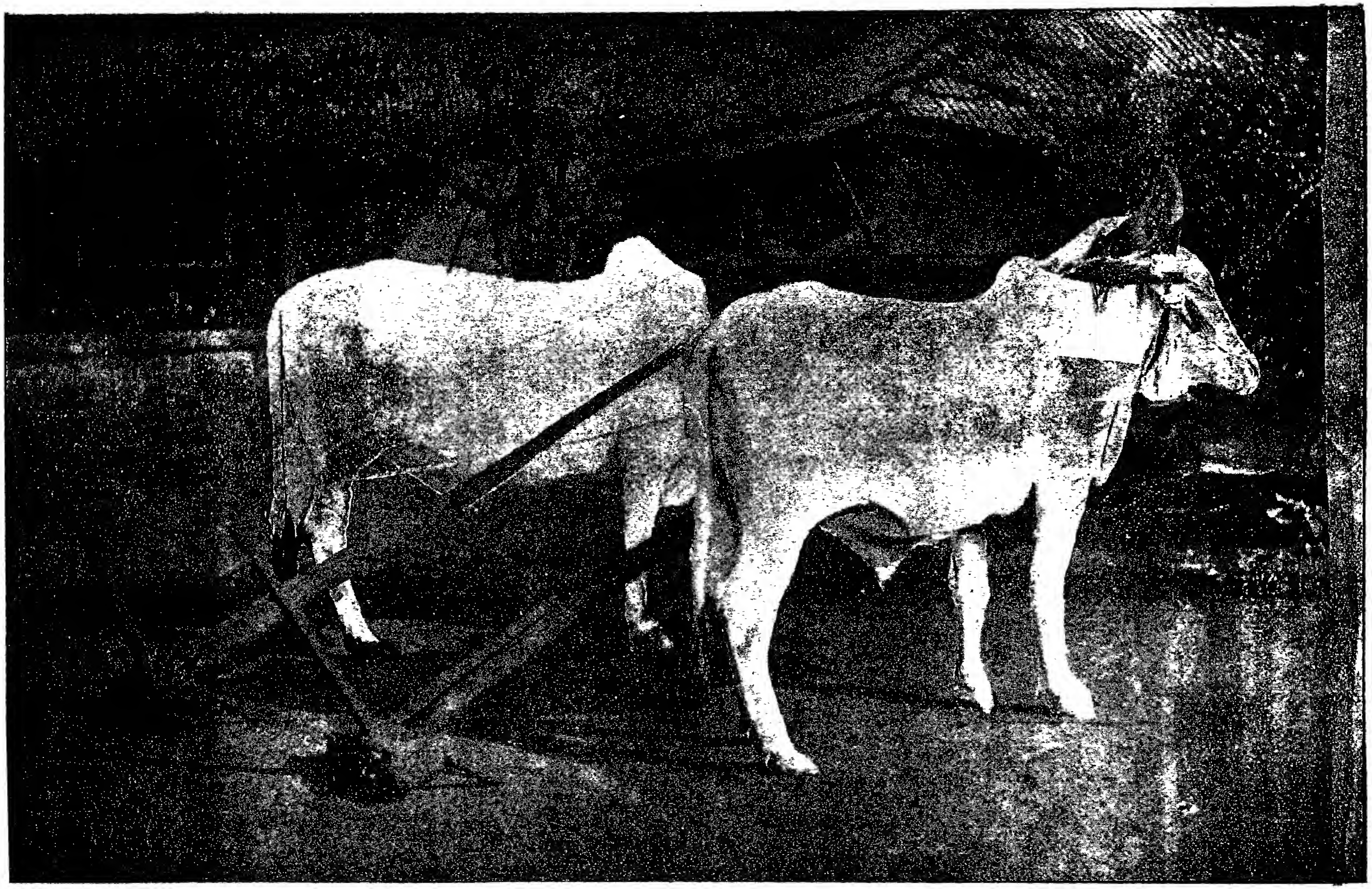
BULLOCK HOE—*KOLPA*-Deccan; *YEDI-KUNTI*—Karnátak. Ill. 15.

Description.

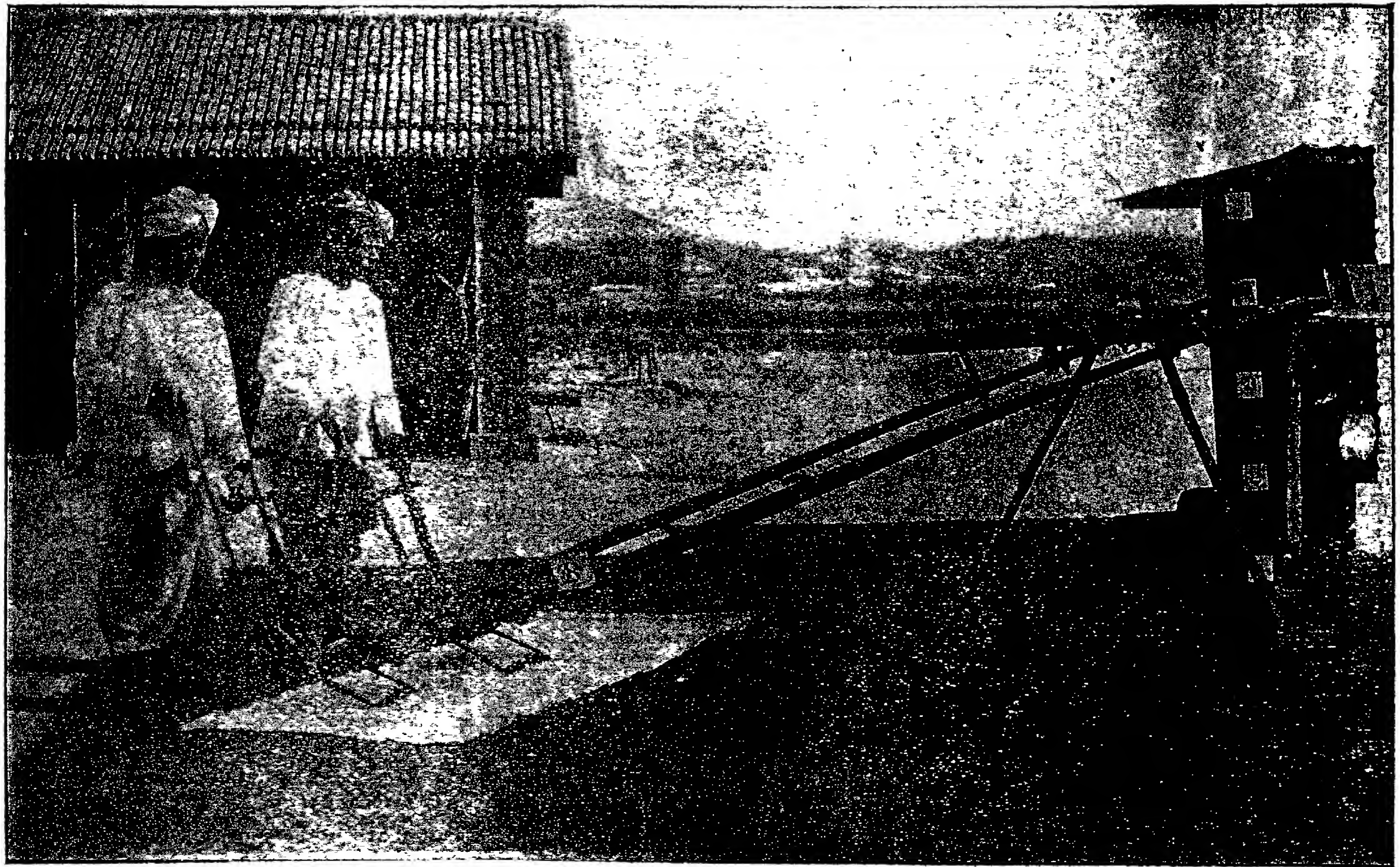
The *kolpa* is essentially a bullock hoe. Each *kolpa* has two cutting blades with a space between of 2 inches. Each blade is 5 or 6 inches long, but is made of a piece of iron 16 or 18 inches long, one end of which is hammered to form the blade, whilst the other is bent up at right angles and forms the stay which connects the blade with the beam. The beam and other parts of the *kolpa* are constructed exactly like a harrow on a small scale, the blade and prongs of the harrow being replaced by the two cutting blades referred to.

Use.

The *kolpa* is driven so that the row of growing crop passes through the space between the blades. In this way the soil is stirred. The crop is weeded between the rows and as near as possible to the rows. The rows are weeded by hand. The *kolpa* being a light implement is usually worked in pairs, which are drawn by one pair of bullocks, but each *kolpa* is carefully guided by one man. The *kolpa* can be used with advantage when the crop is well advanced. But the implement is not used until the crop has made some progress. The cost of a pair is Rs. 4.



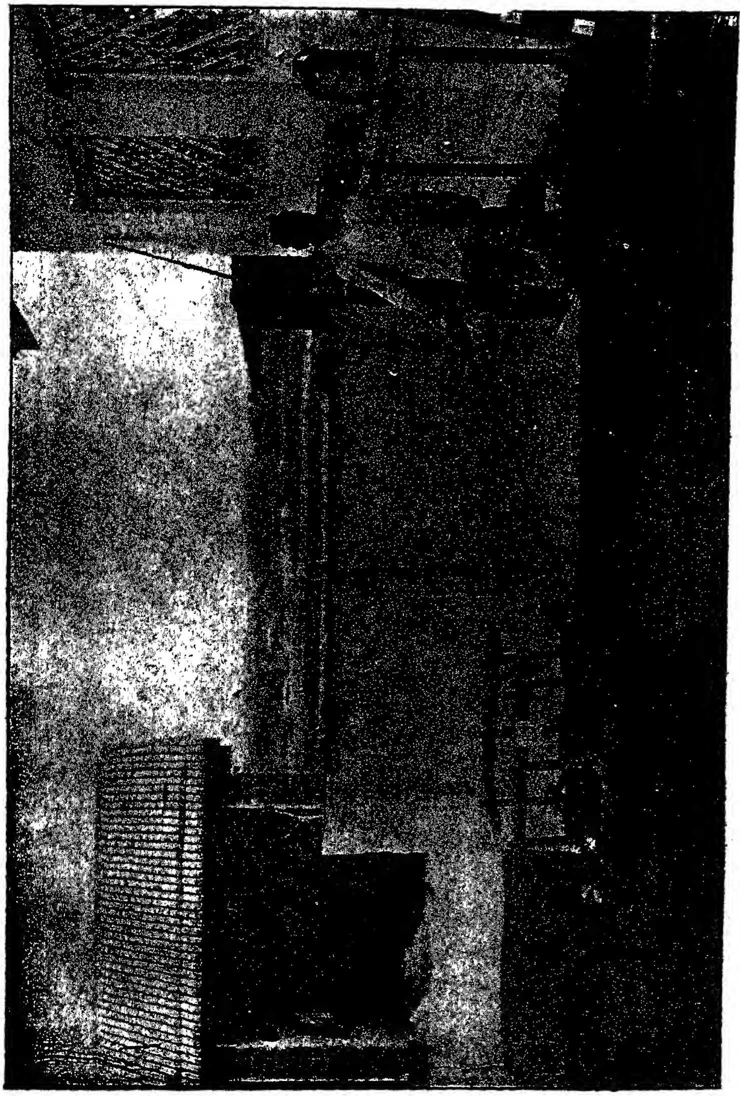
14.—Gujarát bullock hoes (*karabdi*).



15.—Deccan bullock hoes (*kolpa*).

KHIRLE or *GHASE* (draw-cart or sledge for rice seedlings). Ill. 16.

This sledge of the Ghát districts of the Deccan is made entirely of wood; any soft common wood will do. The platform is so made that all the parts give easily. On it the seedlings are laid in neat bundles and it is Description and u



16.—Draw-cart or sledge for rice seedlings (*khirle*).

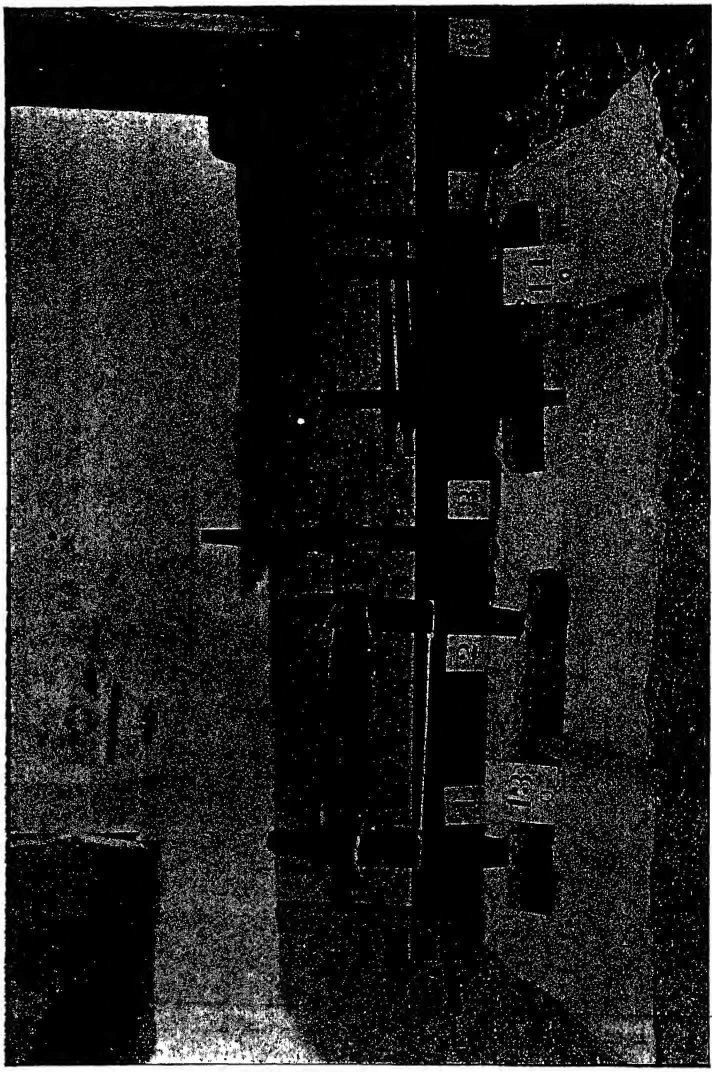
drawn generally by men over the embankments and through the ruts and water-ways of the rice fields, where no cart could go and yet without dropping one bundle of seedlings. The draft rope is attached to the end with curved prow. This sledge is used to carry rice seedlings from the seed bed to the field for transplantation.

The *khirle* costs about Rs. 2.

COTTON GINNING MACHINE—*CHARKO*—Gujarát ; *CHARKA*—Deccan ; *CHARAK*—Karnátak. Ills. 17 and 18.

Description and use.

The implement is securely fixed to the ground so that at work it does not shift its position. A fly-wheel attached to one roller (the iron one) is worked by a woman by means of a handle fitting loosely, or as in Gujarát by means of a supple wand, one end of which fits into the fly-wheel and



17.—Hand gins for cotton (*charka.*)

the other into a hole near the top of a wooden post set upright in the ground. Another woman turns the handle fixed to the other wooden roller on the opposite side and feeds the cotton. (*See illustration 18.*) The rollers revolve towards each other, *i.e.*, each in an opposite direc-

tion; therefore they seize the lint as the cotton is fed. They are so close that the seed cannot pass through with the lint. Generally one of the rollers is of iron; sometimes (as in No. 14 of illustration 17) both rollers are of wood worked through the medium of a male and female screw by one handle; but this pattern is nearly obsolete. Sometimes each roller carries a fly-wheel and such gins are lighter to work. The ordinary pattern (like No. 13 of illustration 17) does excellent work either with indigenous or exotic cotton.

Steam gins have taken the place of hand gins extensively.

The implement is seldom used now in Gujarát. Its place has been taken by steam gins. In Khándesh it is still extensively used, but not much in Dhárwár and the Southern Marátha Country. Cultivators in many parts get their seed from the ginning factories. This is a great mistake. The seed for sowing should be selected in the field, the best bolls of cotton being picked from the most vigorous plants and the hand gin should be used for separating the lint. A hand gin is less liable to hurt the germinating power of cotton seed than a steam gin. Moreover, if the work is done at home there is a guarantee that the seed is select, not contaminated with the larvæ of boll-worm, and of pure variety.

A hand gin can be made in any village and costs about Rs. 3.

HATTIKUDA (foot-roller or roller-gin).

Description.

The foot-roller is a rude primitive machine. The chief parts are (1) the three legged wooden stool on which the ginner sits, (2) the flat stone about one foot by 6 inches and 2 inches thick, (3) two wooden sandals, and (4) the iron pin or roller (*kuda*) about one foot long and tapering from about ½ inch in diameter in the middle to a point at each end.

Roller gin at work.

The foot-roller is worked only by women. In using the foot roller the seed cotton is laid in the sun, frequently turned, and when well dried is sharply beaten with a thin bamboo, called *chhadi*, that it may be as loose as possible for ginning. The woman sits on the stool, the upper lip of a bag being placed on it and the lower lip projecting from under the stool. The sandals are put on the soles and the feet are placed on each end of the roller, which works on the smooth stone. The woman feeds seed cotton with the right hand and rolling the pin with her feet, separates the seed which comes out in front from the clean cotton which comes out behind. The clean cotton is received by the left hand and pushed into the bag under the stool.

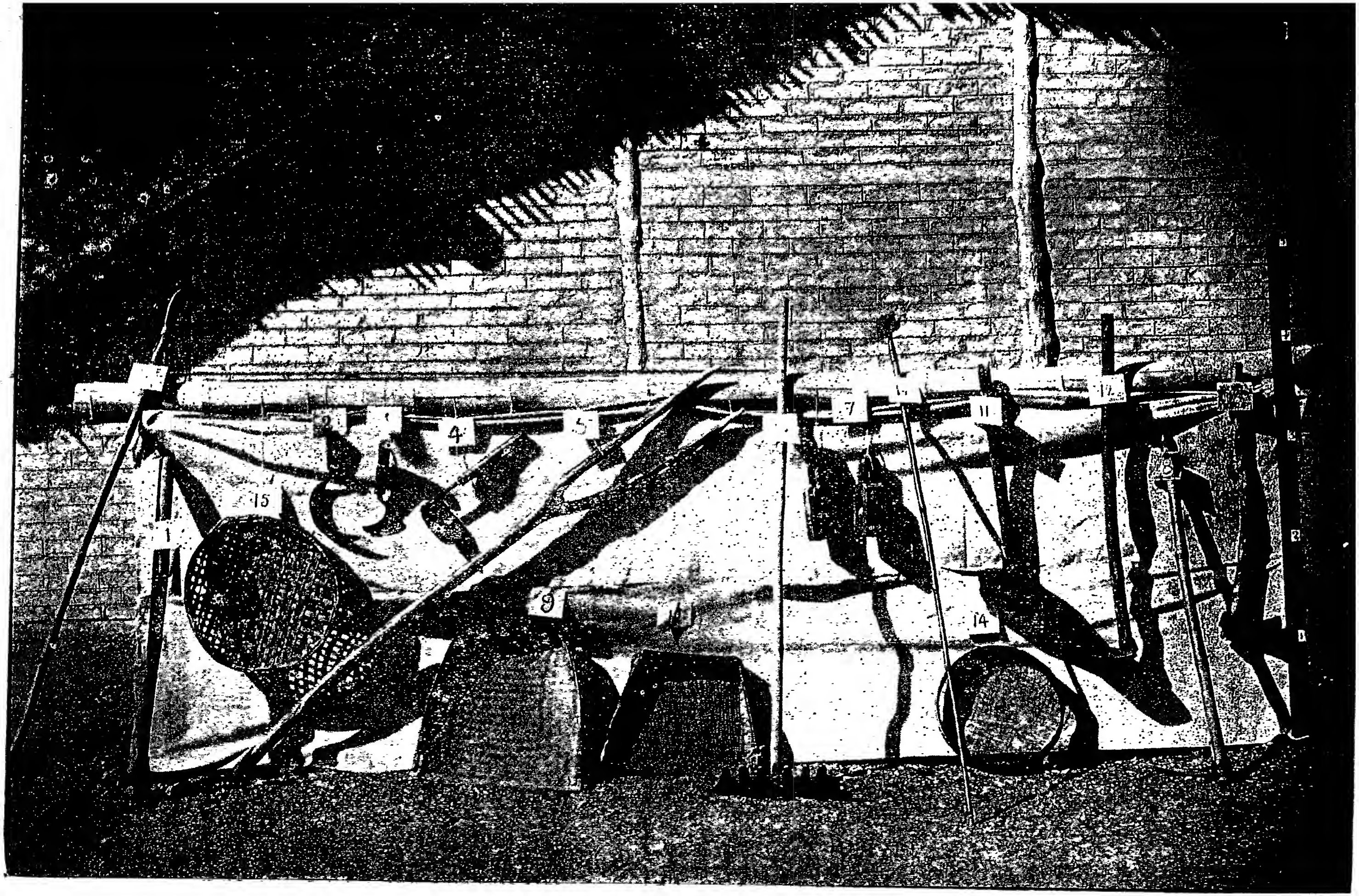
This machine gins indigenous cotton only. It is the only machine that separates the seed without harming the fibre. At the same time, the process is very slow.

The stone, pin, &c., together weigh about 7 lbs. and cost Ans. 10 to Re. 1.

18.—Gujarát hand gin at work.

GUJARÁT HAND TOOLS. III. 19.

Illustration 19 exhibits the various hand tools ordinarily required by a Gujarát cultivator. The sizes can be gauged by the 5 foot measure placed upright at one end. **No. 1** is a heavy pick (*chánchvo*) used for digging out patches of deep rooted weeds in deep black soil. This is done in the fair season after the soil has fissured or cracked. The pick is inserted as far as possible in the cracks and big lumps of earth are levered out. The soil is thus dug to a depth of 1 foot at least. The work is done much more expeditiously than if attempted when the soil is moist. This tool is also used for digging out yams and sweet potatoes. The smaller pick **No. 8** (*kodáli*) is used when the depth of soil to be dug is not great. A still smaller size is used for lifting potatoes, turmeric, ginger, onions and crops of that class. The bigger size costs Ans. 12 to Re. 1. **No. 2** (*dátardu*) is a grass-cutting sickle which will be more fully described under illustration 21. **No. 3** is a weeding hook called *dátardi* (Gujarát), *khurpa* (Deccan), *kurchigi* (Karnátak). **No. 4** is a little hand weeding hoe (*dhariun.*) This is an excellent tool which ought to be in general use in other districts. Both edges can be used for stirring the soil and uprooting weeds. It costs Ans. 8. Generally the blade of a weeding hook as used in the Deccan is more bent than that of **No 3.** (*See Nos. 27 and 29 of illustration 21*). The *dátardi* or *khurpa* is generally made from the blade of a worn out sickle. The blade is steel or chilled iron and is ground to an edge both back and front. It is fitted as shown in illustration into wooden haft. The *khurpa* is used for hand weeding and for stirring the surface soil along the rows of young crops and between the rows in such crops as cannot be bullock hoed. In the Konkan and rice tracts of Karnátak a small weeding hook is not used. A sickle (*vila*) is used for the double purpose of weeding and harvesting. A *khurpa* costs Ans. 2 to Ans. 4. **No. 5** is a thorn fork (*surku*—Gujarát). This is simply a forked branch of any tough hardwood tree cut and shaped to give two prongs and a tolerably long handle. It is used to collect thorns for hedges, for collecting *ráb* material and on the threshing floor to stir up from time to time the grain, *bhusa* and straw as the grain is being trampled out. **No. 6** is a hand rake (*panjethi*—Gujarát: *gavri-hallu*—Karnátak) used on the threshing floor to gather in and stir up the pile of straw, chaff, &c., as the grain is being trampled out under the feet of bullocks. It is also used to level the surface of beds laid out for irrigation and cover the seed sown in such beds. It costs Ans. 4 to Ans. 8. **No. 7** are pulley blocks (*goli*—Gujarát) used to help in securely tightening the ropes used to bind on a cart a load of grass or any other light bulky material. **Nos. 9** and **10** are two patterns of the winnowing scoop (*sup*—Deccan, Gujarát, Konkan; *mara*—Karnátak).



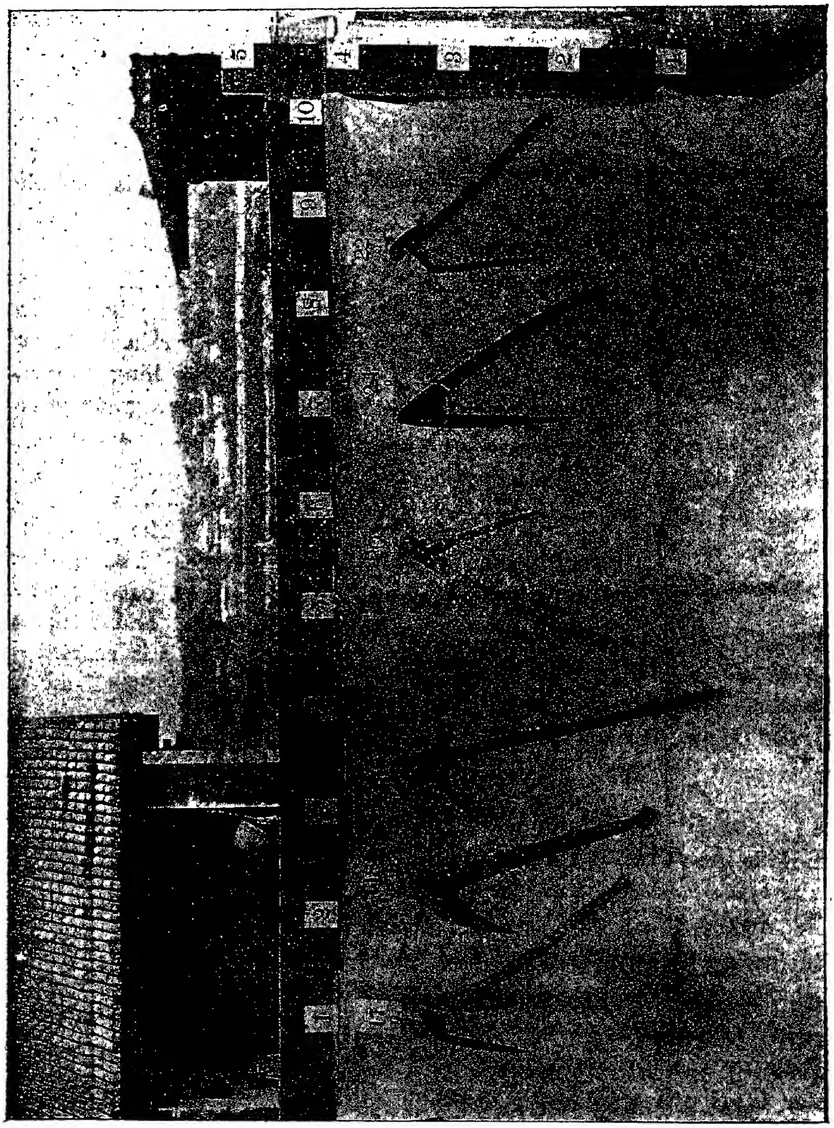
19.—Gujarát hand tools.

The *sup* is used for winnowing grain. The trodden corn mixed with broken chaff is put into the *sup* and from a height poured when wind is strong enough to carry off chaff and light grain. The good grain is further cleaned of earth particles and other inpurity by means of the *sup*. The women of every *rayat's* household can use the *sup* very deftly at the work. It is used also to separate cleaned rice from husk and dirt after being pounded. It costs Ans. 4 to Ans. 6. **Nos. 11** and **12** are hand hoes (*pávado*-Gujarát ; *khore*—Deccan ; *saliki*—Karnátak). This tool takes the place of a shovel or spade as used by an English labourer. It is used in all earth work, in digging pits, making embankments, forming beds and water channels for irrigation, to regulate the distribution of water in irrigation, in cleaning roadways and for many other uses. These hand hoes vary in size and shape according to the use they are put to and cost about Ans. 12 each. **No. 13** is a hatchet (*koháḍi*—Gujarát ; *kurháḍ*—Deccan and Konkan ; *kodli*—Karnátak) made of English wrought iron with steel edge, and it is used for the ordinary purposes for which a tool of this sort is required. It costs Ans. 12. **No. 14** is a bamboo sieve (*chárno*). It is used on the threshing floor in handling the threshed grain and chaff as winnowing is done; also in handling grain and seed. **No. 15** is a riddle or sieve (*chárno*). It is used on the threshing floor like No. 14 ; also to separate grain from chaff when the wind is not strong enough for winnowing in the usual way. **No. 16** is a bill-hook (*koyta*—Deccan and Konkan ; *kandali*—Karnátak ; *dharia*—Gujarát.) Other specimens of the same tool are shown as **Nos. 43, 44** and **45** of illustration 22, and short handled ones as **Nos. 25** and **33** of illustration 21. The blade is a straight reaping hook and has either a smooth or saw edge. The bill-hook is used for various purposes ; cutting and trimming hedges, cutting wood, lopping branches and cutting thorns required for *ráb* material and fuel, &c. It costs Ans. 8. **No. 17** is a plough spud (*vaso.*). This is carried by ploughmen in Gujarát. There is a spatula-like iron piece fitted on one end of the solid thin bamboo handle, and a brad-awl is fixed on the other end. The spatula is used to clean the plough or other tillage implement of adhering moist earth as the implements are turned on the headlands. The brad-awl end is used to goad the bullocks when they get tired or lazy. The handle is long so that the driver can reach the bullocks without special effort.

Native picks

Illustration 20 exhibits various kinds of native picks. The sizes are indicated by the upright and horizontal measures marked in feet. The most primitive of these are those marked **Nos. 18** and **21** and are called respectively in the Konkan, *nángat* and *kudávana*. The working point of the latter is tipped with iron ; in other respects both tools are identical. They are hardwood hand picks made from forked branches, and are used for digging earth for covering *ráb* material, for pounding the lumps to a fine consistency and for hand-digging the seed beds in which the seedlings of rice and hill millets are raised in the uplands of the Konkan. **Nos. 17** and

20 (*tikam*—Gujarât; *tikáv*-Deccan) are in very common use, chiefly for digging and loosening earth. **No. 22** differs from these in having the point of the pick hammered to a flat cutting edge. This latter implement is chiefly useful in cutting through roots when trees are uprooted. These implements cost about Ans. 12 each. *Vaddár khore*



20. Picks.

(a digging spade). The blade is of steel, strong, powerful and 15 to 18 inches long and fitted like a hoe into a powerful hardwood handle 3 feet long. The blade tapers from a width of 9 inches at handle

to about 3 inches at point. It is used by *Vaddárs* (professional diggers) with great effect and precision, especially in black soil set hard in the fair season. The spade is slung over the head with two hands and driven into the soil with great force, in the same spot exactly, until deep enough to take a firm hold, when the lump of earth is levered out. It is used at Railway works, road making, forming ditches and trenching new land broken up from waste.

Illustration 21 exhibits various kinds of sickles, weeding hooks and bill-hooks.

21.—Sickles and weeding hooks.

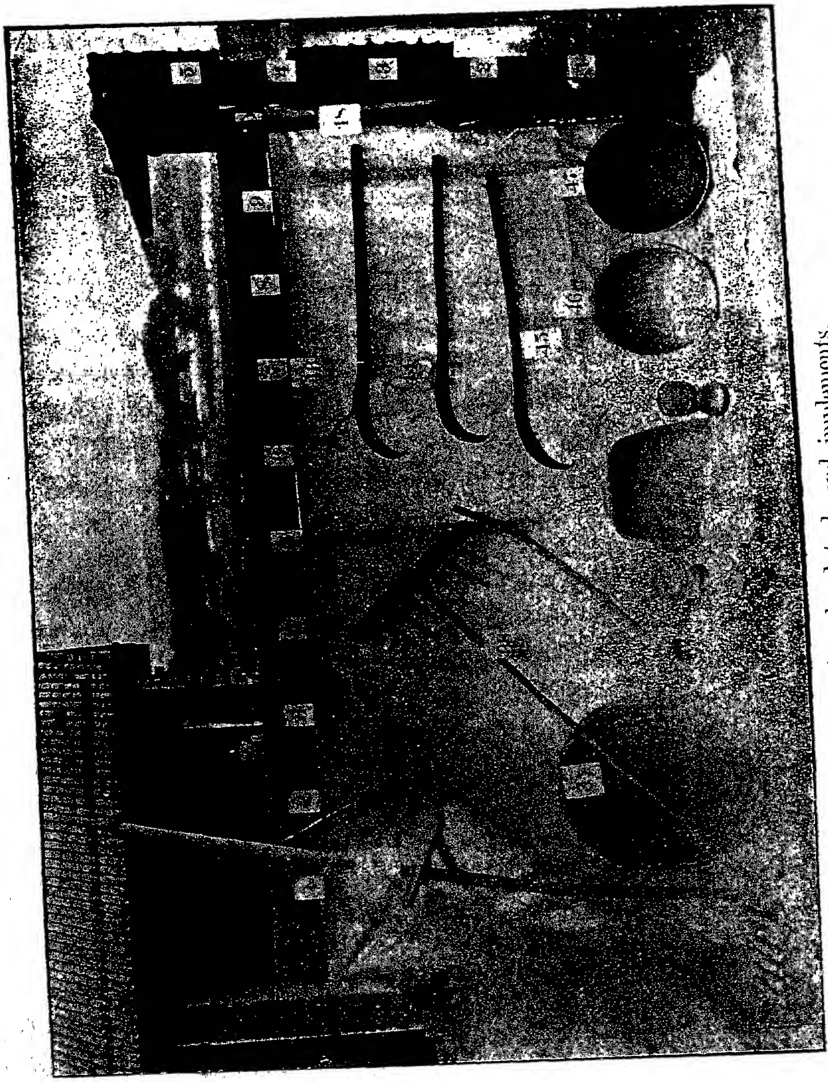
Sickles and weeding hooks.

The sickle is called *dátarda*—Gujarát; *víla*—Deccan and Konkan; *kudagolu*—Karnátak. Those used for reaping grain crops or for grass-cutting are all much of the same pattern. The Gujarát sickle has either a plain or a saw edge. The Deccan sickle has a plain steel edge. The Karnátak sickles Nos. 26 and 28 of illustration 21 are much larger and are plain edged. A saw edged sickle is considered best for reaping rice and plain edged sickles for the larger millets. Sickles range in price from Ans. 12 to Re. 1.

Nos. 34 and 35 of illustration 21 are large sickles (*hali-koyyuva-kudagolu*—Karnátak) used in cutting the grass on the embankments of rice beds. They are unwieldy and smaller sickles would probably do the work better and more expeditiously. They cost Rs. 4 each.

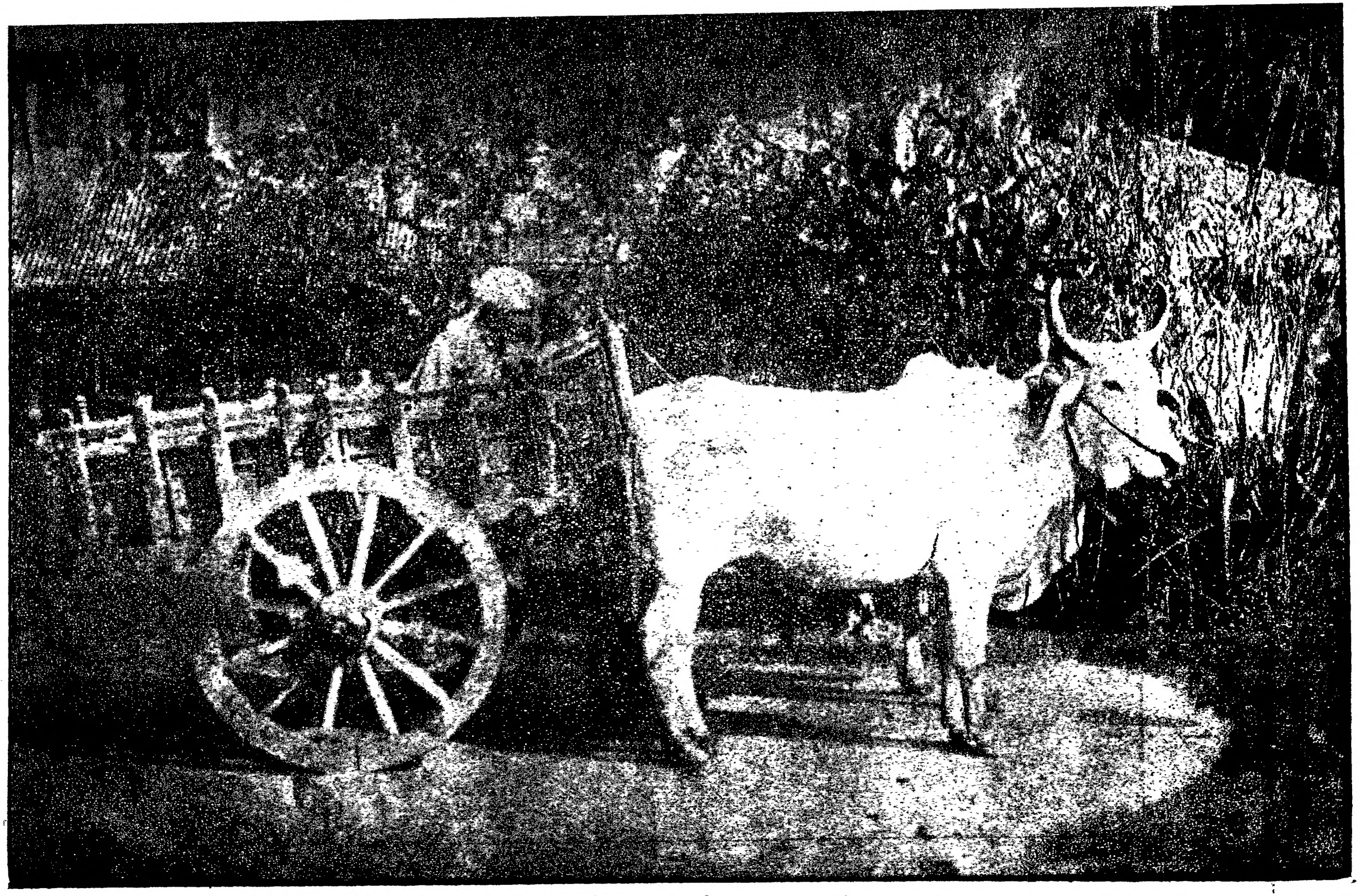
Various hand tools.

Illustration 22 exhibits various hand implements. The sizes may be gauged by the upright and horizontal measures marked in feet. No. 36 is a carrying pole (*baila*—Konkan). It is used in every village. It is a hardwood pole pointed at one end. Near the middle a through pin of hardwood passes through the pole. A slab of wood one foot long and 8 inches wide has a hole near one end through which the pointed end of the pole is passed. This slab rests on the through pin. The *baila* is used to carry large bundles of loppings, grass or other *ráb* material from the forest to the rice fields. The bundle when gathered is securely tied. The pointed end of the *baila* is then thrust through it. The bundle rests on the wood slab. The slab, if padded below, rests comfortably on the head of the carrier, and the but end of the *baila* can be placed on the ground from time to time to allow the carrier to rest as his load is carried home. A heavy load can thus be carried a long distance. No. 37 is a shallow wicker basket made of cotton or *tur* stalks for carrying head-loads of manures. No. 46 is a deeper bamboo basket used for handling grain. Nos. 40 and 42 are grain measures of the common type. No. 47 is the iron *ghamelo* in which milch cattle get their oil-cake, cotton seed, &c. No. 48 is a dyke or rice field embankment shovel (*pendse*—Konkan). This is a sort of a paddle with a blade 3 feet long and handle two feet long. It is home made and used to beat the embankments of rice fields into proper shape as they are built up of soft mud. No. 49 is a stool (*tivai*—Konkan) used as a seat in the muddy rice fields while pulling the rice seedlings ready for transplantation. The tediousness of lifting seedlings from wet mud is thus somewhat relieved.



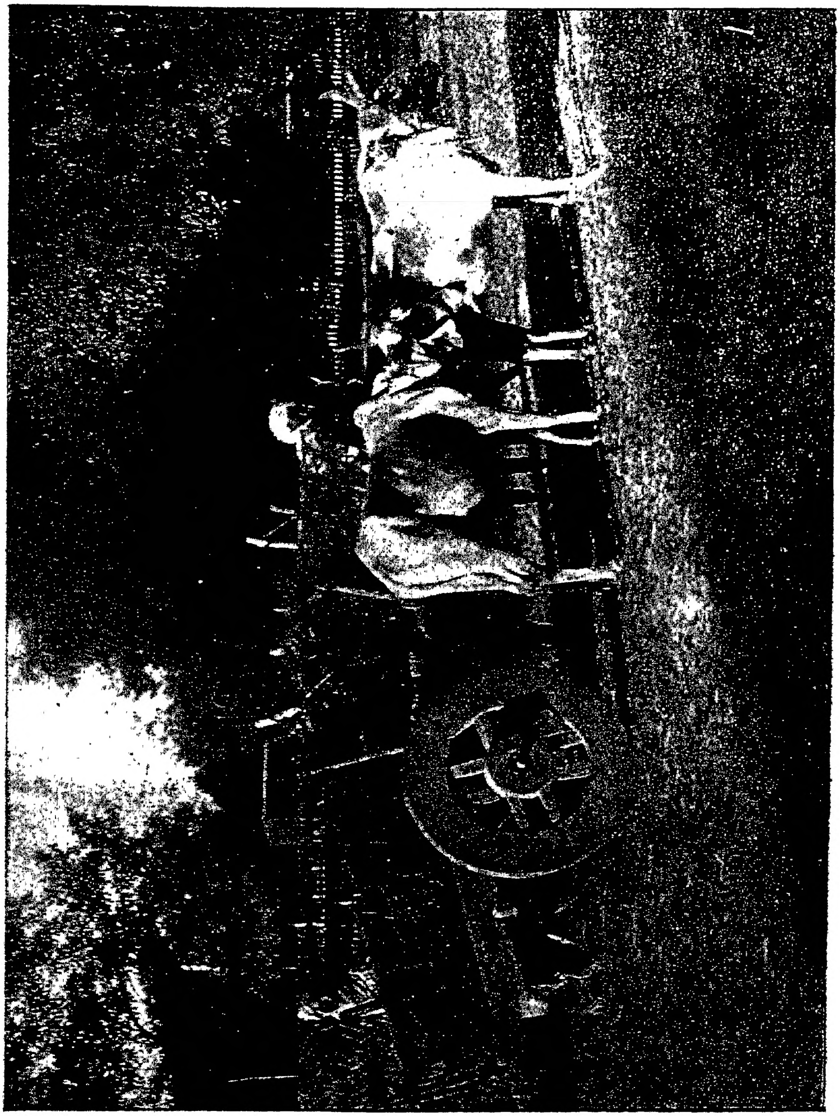
22.—Various hand tools and implements.

Illustration 23 shows an ordinary type of cart as found in various agricultural districts in the Presidency with good made roads. A cart of this class costs Rs. 60 to Rs. 75.



23.—A bullock cart of common pattern.

Illustration 24 shows the common kind of cart found throughout the *gorádu* soil tracts of Northern Gujarát, Kaira, Ahmedabad and Baroda territory. There are practically no made roads in these dis-



24.—Common cart of Northern Gujarát.

tricts and in the monsoon they are often knee deep in mud and water, and in the fair season ankle deep with fine sand. This cumbersome cart drawn by two big Gujaráti bullocks or by four small ones, is capable of carrying heavy loads over these *kacha* roads.